Utilizing statistics in research: A case study

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Many college and university educators would like to incorporate statistical findings in their own research papers but are often unsure of where to start. Some have tried their hand at statistics, only to be disappointed when a resulting p-value of greater than 0.05 leads them to conclude that their research results are statistically insignificant, when in actuality the results are significant when sample effect size is taken into consideration. Two commonly used statistical analyses, the t-test and chi-square test, as well as various statistical terms such as p-value, Cohen's d, phi value and R^2 will be introduced and explained in-depth. The importance of sample effect size in conjunction with p-value will also be explained. By going through the process of formulating and analyzing an actual survey from start to finish, it is hoped that readers will gain confidence in being able to utilize SPSS to publish their own research findings, while at the same time being able to better understand and interpret basic statistical figures often found in academic papers.

大学教師の多くが自分の研究論文に統計結果を取り入れたいと考えているが、何からはじめるべきか分からないことがしばしばある。統計学に取り組もうとする教師もいるが、p-値が結果的に0.05を超えてしまい、その研究結果が統計学的に意味を持たないとの結論に至り、失望するという結果に終わっている。この時も、サンプルのエフェクトサイズを考慮に入れていれば、その結果は意味のあるものだったはずである。本論では、筆者が先の論文でアンケート調査の統計結果をSPSSを利用して公表した際の段階的な手順を明らかにしたい。t-検定やカイ二乗検定といったふたつの一般的な統計分析の他にも、p-値、 Cohen's d-値、phi-値やR2などの様々な統計用語を取り入れて詳述する。また、ひとつひとつの統計分析を行うために、どのような手順を踏むべきか正しく分かるように、本論中、SPSSソフトのアウトプットスクリーンを利用する。併せて、p-値と併用するサンプルのエフェクトサイズの重要性についても説明したい。実際の調査の組み立てと分析の全過程を確認することにより、教師が将来、研究調査結果を公表する際に、SPSSを自信を持って利用でき、併せて、SLA分野の学術論文にしばしば見られる基本的な統計学上の数字をより深く理解し、解釈できるものと思われる。

What exactly is statistics?

Statistics is the science of collecting, simplifying, and describing data, as well as making inferences (i.e., drawing conclusions) based on the analysis of data. To put it in a more interesting and simple way, "Statistics is the art of making numerical conjectures about puzzling questions" (Burrill, 1996).

Statistics is about discovery and proof: finding clues, suggesting conclusions and then testing whether those conclusions are true or not. The most important goal for statistics is to tell a reasonable and credible story about information in numerical form.

There are two main branches of statistics: descriptive and inferential. Descriptive statistics deals with collecting, simplifying, and describing properties of data, whereas inferential statistics involves drawing conclusions about a population based on a sample. This paper will deal mainly with inferential statistics.

Why the field of statistics is important to research

Statistics give an added sense of validity to research papers. That is mainly due to the fact that researchers are able to talk in not just abstract terms but rather are able to give supporting evidence to back up their theories and points of view. In recent years especially, statistics have been used more and more in the field of SLA to "carry out a more rigorous, empirical approach to research as practitioners more formally investigate teaching practices. The word 'data' turned up 178 times among the 700 abstracts submitted this year [for JALT2008], which is about a 25% hit rate" (Stapleton & Collett, 2008).

Quantitative *facts*, graphs, and tables often appear in the popular media as well as research papers. Understanding the uses (and abuses!) of quantitative information has become an important part of modern literacy.

The main questions researchers need to ask themselves when looking at statistics or analyzing their own are: (1) How do we know this is true? (2) How strong is the evidence? (3) Are there other potential explanations for this result? and (4) What is this statistical result being compared to? As an example of the last question, it is ambiguous for a newspaper headline to simply state: "Crime drastically reduced." It is important for the reader to examine the full article to ascertain to what time period this figure is being compared.

Original survey methodology

With the above in mind, my proficiency in Japanese led me to ask three questions regarding my use of Japanese (L2) in the English (L1) classroom:

(1) How much Japanese do students want their native English-speaking teacher (NEST) to use?

(2) Is it more desirable to have a NEST who can speak Japanese or not?

(3) What are the benefits and drawbacks of Japanese use by NESTs in the EFL classroom?

In particular, I wanted to test the statistical validity of two hypotheses:

(1) Students with a remarkably higher level of English proficiency (in this case, those who have studied abroad) prefer the NEST to use less Japanese in English class.

(2) Students of different proficiency levels within the same type of English class have differing views regarding the amount of Japanese they prefer the NEST to use.

To find answers to these questions, a survey was conducted on 191 university students (Norman, 2008, p. 699). The four survey questions correspond to the three questions above, with question number three being split into two separate questions. Statistical analyses were performed on only questions one and two, which were both of the closed-ended type. (Simple data manipulation for averages, etc.—such as Tables 1 and 2 in my original paper (Norman, p. 695)—can be done easily through Excel and then transferred into simple tables in MS Word.) Questions three and four were open-ended questions and therefore could not be analyzed statistically. The original data set used to carry out the statistical analyses in the remainder of this paper can be found in Appendix 1. Readers are highly encouraged to input this data set into their own SPSS program to recreate the same results.

Hypothesis 1: T-test, p-value, and Cohen's d

To test the first hypothesis, it was necessary to run a t-test using SPSS. A t-test is used to look at the difference between the means (i.e., averages) of a continuous variable (e.g., height, weight, age, test score, etc.) between two groups. This is known as bivariate analysis. In the case of my survey, the students were divided into two groups based on whether or not they had studied abroad. The resulting groups were labeled *S.A.* (students who had study abroad experience) and *Others* (combination of the two sub-groups *L.S.* and *Rehab*).

Using SPSS, the following steps were used to carry out the t-test:

(1) Choose *Analyze*

(2) Choose *Compare Means*

(3) Choose *Independent-Samples T-test*

(4) Select *useofjap* and press the top arrow (This is the dependent variable.)

(5) Select *typeofs* and press the bottom arrow (This is the independent variable.)

(6) Click *define groups* and type in *regula* and *abroad* (These are the two groups.)

(7) Press Continue

(8) Press OK

The resulting SPSS output screen will appear as shown below.

Looking at Table 1, it is first important to look at the resulting *Sig.* number. A number greater than 0.05 means that the variance between the two groups can't be said to differ and indicates that the upper row of numbers must be used. Conversely, a number of less than 0.05 means that the variance between the two groups is possibly different and, subsequently, the bottom row of numbers must be used. In this case, the resulting 0.179 number indicates that the upper row of numbers must be used for the analysis.

When reporting results of a t-test in an academic paper, the three figures that must be given are the t-test statistic itself (=t), the degrees of freedom (=df) and the p-value (=Sig. (2-tailed)). In this case, the figures would be written as follows: $t=3.826$, $df=188$, $p<0.001$. (Although $p=0.000$ is displayed in the table, it is impossible to be 100% confident that there is a true difference between the means of the two groups, so researchers report such a result as $p<0.001$.) The

Table 1. SPSS output screen for hypothesis 1

Group Statistics

	TYPEOFST	N	Mean	Std. Deviation	Std. Error Mean
USEOFJAP	Regula	180	44.26	18.929	1.411
	Abroad	10	20.00	28.771	9.098

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
USEOFJAP	Equal variances assumed	1.819	0.179	3.826	188	0.000	24.26	6.340	11.749	36.762
	Equal variances not assumed			2.634	9.438	0.026	24.26	9.207	3.574	44.937

Note: Because both of the tables above appear on the same SPSS output screen, they have been labeled together as Table 1.

p-value is the number that researchers are most concerned about. (Although the values of "t" and "df" are not important in and of themselves, they still need to be included in the reported results so that other researchers are able to replicate the results.) Most researchers accept a p-value of $p<0.05$ for significance. This means that we can be 95% confident that the results are due to a real difference in the population (i.e., data) and not due to sampling error or any other chance factors. One common misconception is that a lower p-value means a better result. However, this is not the case. Rather, the lower our resulting p-value is, the more confident we can be that there is a statistical difference between the means of the two groups we are talking about. In our case, a $p<0.001$ means that we can be 99.9% confident that there is a statistical difference between the two groups, *S.A.* and *Others*.

Although a low p-value is a good result, it does not signify how strong the relationship is between the two groups. To test for this, known as effect size by researchers, Cohen's d statistic needs to be used. Unfortunately, SPSS software does not calculate this statistic. However, all the numbers needed to do the calculation are located in the output screen.

Cohen's d = (Mean group A – Mean group B) ÷ [(Std. deviation group A + Std. deviation group B)/2]

- Below 0.20 = weak effect
- 0.21~0.50 = modest effect

- 0.51~1.00 = moderate effect
- Above 1.00 = strong effect

Using the output screen shown above, Cohen's d can be calculated as: (44.26 – 20.00) ÷ [(18.9+28.8)/2] = 24.26 / 23.85 = 1.02

So in this case, a resulting Cohen's d statistic of 1.02 indicates that there is a strong effect between the two groups.

Effect size is an important calculation and should be included with research results whenever possible. It is especially important in the case of small sample sizes (i.e., less than 30) because a resulting p-value above the widely accepted $p<0.05$ can lead many researchers to reject their own results as statistically insignificant, when in fact they are significant if effect size is taken into consideration.

Hypothesis 2: Multiple linear regression

To test the second hypothesis, it was necessary to run a multiple linear regression using SPSS. Multiple linear regression looks at the relationship between several predictor (i.e., independent) variables and one effect (i.e., dependent) variable. This is widely known as multivariate analysis and is usually noted by the term R^2 (R-squared). Essentially R^2 tries to measure how well our model fits the data we have.

Since my goal was to test to see if there was a difference between the amount of Japanese that students of varying levels within the same English class wanted the NEST to use, I chose *Final exam score* as my predictor variable and *Desired use of Japanese by the NEST* as my effect variable.

Using SPSS, the following steps were used to carry out the analysis:

(1) Choose *Analyze*

(2) Choose *Regression*

(3) Choose *Linear*

(4) Choose *useofjap* and press the button next to *Dependent* (This is the dependent variable.)

(5) Select *testscor* and press the button next to *Independent* (This is the independent variable.)

(6) Click *define groups* and type in *regula* and *abroad* (These are the two groups.)

(7) Press *OK*

The resulting SPSS output screen will appear as shown below. (The SPSS output tables for ANOVA and Coefficients were omitted due to their irrelevance to the analysis being done and also for space considerations.)

The most important number we need to look at in Table 2 is the R Square statistic. It will always be a number between 0 and 1. As a general rule of thumb, R^2 results can be interpreted as follows:

- <0.1 = poor fit
- 0.11~0.3 = modest fit
- 0.31~0.5 = moderate fit
- >0.5 = strong fit

Table 2. SPSS output screen for hypothesis 2

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	TESTSCOR[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: USEOFJAP

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.281	0.079	0.065	16.620

a. Predictors: (Constant), TESTSCOR

Note: Because both of the tables above appear on the same SPSS output screen, they have been labeled together as Table 2.

In our case, R^2 equals 0.079, which means that our model is a poor fit. In other words, it can be said that there is very little correlation between high and low achievers in the same English class regarding the amount of Japanese they prefer the NEST to use in the EFL classroom. This result can be more easily understood by taking a look at a plot graph of all of the data points (Figure 1).

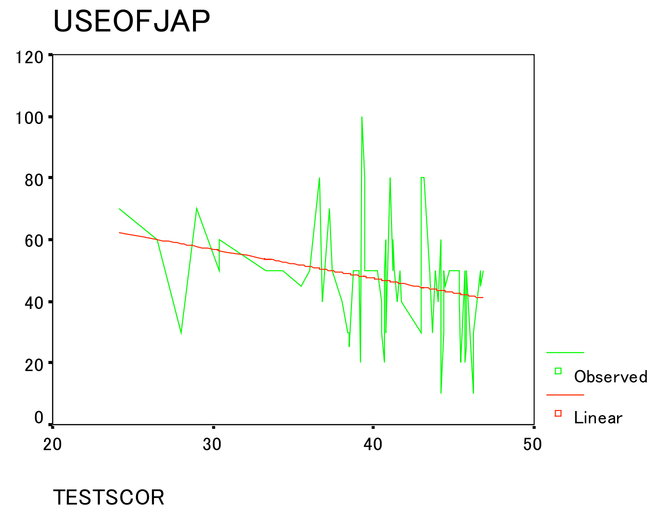

Figure 1. SPSS output screen for R2 fit model

It is clear from looking at Figure 1 that all of the data points (i.e., students' opinions on how much Japanese should be used by the NEST) are quite scattered and many of them are far away from the *best fit* line that SPSS calculated using the provided data, thus the low correlation result of only 0.079. Essentially, this means that the second hypothesis (i.e., that students of different proficiency levels within the same type of English class have differing views regarding the amount of Japanese they prefer the NEST to use) was not confirmed.

Survey question 2 analysis: Chi-square and phi

To carry out analysis on survey question 2, it was necessary to run a chi-square test using SPSS. As was the case with the previously explained t-test, the chi-square test is also a type of bivariate analysis. However, it is important to note that t-tests are used for continuous variables, whereas chi-square tests are used to look at the difference between the means (i.e., averages) of nominal or ordinal variables. A nominal variable is one such as gender or ethnicity, where any numbers we give to the values (e.g., 1 for boys and 2 for girls) only serve to replace a name. On the other hand, an ordinal variable is one that contains a natural ordering of categories and which is often used to code research questionnaire responses (e.g., 1=strongly agree, 2=agree, 3=disagree, and 4=strongly disagree).

Looking at Table 2 of my original paper (Norman, 2008, p. 695), there appears to be a large difference between the responses obtained from the *S.A.* and *Other* groups of students. However, one doesn't know how likely it is that this difference would occur in the sample if there were really no difference in the population at large because the result could have been due to a sampling error or other chance factors. Therefore, a chi-square test was carried out to statistically analyze what the likelihood of this was.

Responses to the survey question, "Would you rather have a teacher in your English class who can speak Japanese or one who cannot?" can be expressed as a nominal variable, where "Yes" = 1 and "No" = 2. As with the previously explained t-test, the two groups in this case were defined as those who had studied abroad before and those who had not. Unfortunately there was one student (located in the last row of the data set) who gave an invalid response and therefore had to be taken out before the chi-square test could be effectively carried out.

Using SPSS, the following steps were used to carry out the chi-square test:

(1) Choose *Analyze*

(2) Choose *Descriptive Statistics*

(3) Choose *Crosstabs*

(4) Select *speakjap* (this is the dependent variable) and click the arrow next to *Row(s)*

(5) Select *typeofst* (this is the independent variable) and click the arrow next to *Column(s)*

(6) Press the *Statistics* button

(7) Click on the square next to *Chi-square*

(8) Press *Continue*

(9) Press *OK*

The resulting SPSS output screen will appear as shown below.

Looking at Table 3, it is first important to note that N=189. This was to be expected as one student's response was invalid and had to be taken out before the chi-square test was run, as previously explained. The second table contains a summary of the data inputted and can be disregarded for our purposes. The third and final table contains the essential information.

When reporting results of a chi-square test in an academic paper, the three figures that must be given are the chi-square

Table 3. SPSS output screen for survey question #2

		Case Processing Summary				
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
SPEAKJAP * TYPEOFST	189	100.0%	0	0.0%	189	100.0%

SPEAKJAP * TYPEOFST Crosstabulation

Count

		TYPEOFST		
		Abroad	regula	Total
SPEAKJAP	no	6	5	11
	yes	3	175	178
Total		9	180	189

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	63.829[b]	1	0.000		
Continuity Correction	52.705	1	0.000		
Likelihood Ratio	26.759	1	0.000		
Fisher's Exact Test				0.000	0.000
N of Valid Cases	189				

a. Computed only for a 2x2 table

b. 1 cells (25.0%) have expected count less than 5. The minimum expected count is .52.

Note: Because all of the tables above appear on the same SPSS output screen, they have been labeled together as Table 3.

statistic itself (=Value), the degrees of freedom (=df) and the p-value (=Asymp. Sig. (2-sided)). In this case, it would be written as follows: chi square=63.83, df=1, $p<0.001$. As with the t-test, the p-value is the number that researchers are most concerned about. (Although the values of chi square and df are not important in and of themselves, they still need to be included in the reported results so that other researchers are able to replicate the results.) In this case, the result of $p<0.001$ means that we can be 99.9% confident that there is a statistical difference between the two groups, *S.A.* and *Others*.

As explained previously, the importance of effect size cannot be understated. The effect size for a chi-square test, known as phi, is a different but simpler calculation than that done for a t-test. Unfortunately, SPSS software does not calculate this statistic. However, all the numbers you need to do the calculation are located in the output screen. Phi is calculated by taking the square root of the calculated value of chi square divided by the overall sample size.

- Below 0.10 = weak effect
- 0.11~0.30 = modest effect
- 0.31~0.50 = moderate effect
- 0.51~0.80 = strong effect
- Above 1.00 = very strong effect

Using the output screen shown above (Table 3), phi can be calculated as: $(\sqrt{63.829 \div 189}) = 0.58$

So in this case, a resulting phi value of 0.58 indicates that there is a strong effect between the two groups. It is important to note that the value of phi likely would have been much higher if not for the small number of students in the S.A. group (n=9) versus all others (n=180).

Conclusions

Statistics can seem daunting at first, even for those who liked studying them during their university days or for those who love numbers. It is crucial to have a clear handle on what you want to research (i.e., your hypothesis/hypotheses) before formulating a survey. Without a clear plan, resulting statistical analyses will at best be difficult to carry out, and at worst the results will be convoluted or misleading.

It is also important to not get overwhelmed by the huge amount of functions (i.e., calculations and options) available in SPSS or other statistical package programs. As is often the case with software programs, 99% of the available functions are unnecessary to be able to do basic data manipulation. And that is certainly the case here with the statistical analyses explained in this paper.

Before formulating your own research questionnaire and then conducting statistical analyses of the results, it is highly recommend that you read a book that covers the basics of statistics in an easy to understand fashion. Books such as *Doing Quantitative Research in Education with SPSS* (Muijs, 2004) and *SPSS Survival Manual* (Pallant, 2005) are very helpful in explaining difficult statistical analyses in a step-by-step fashion. Both books also cover frequently used statistical tests not covered in this paper such as ANOVA (analysis of variance, used when wanting to compare the means of more than just two groups) and MANOVA (multivariate analysis of variance, which is an extension of ANOVA, used when more than one dependent variable exists).

In conclusion, utilizing statistics can help lend credence to research results. When generating a survey, it is important to first ascertain exactly what to research, followed by formulating hypotheses and testing their validity. Then and only then is it possible to construct the proper questions to put into a survey. To verify the clarity and accuracy of the survey questions, it is also a good idea to trial the survey before distributing it on a wider scale. All in all, taking the time to create a clear and easy to understand survey from the beginning can save a lot of time and trouble. In addition, close adherence to these few simple pieces of advice can make the difference between meaningful and misleading statistical results.

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SPSS 11.0 for Windows Student Version (2001). Copyright SPSS Inc., 1989-2001.

Appendix 1

Original SPSS data set for questionnaire

Typeofst	Useofjap	Speakjap	testscor
Regula	30	yes	.
Regula	25	yes	.
Regula	20	yes	.
Regula	30	yes	.
Regula	40	yes	.
Regula	50	yes	.
Regula	20	yes	.
Regula	30	yes	.
Regula	60	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	40	yes	.
Regula	60	yes	.
Regula	50	yes	.
Regula	30	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	25	yes	.
Regula	10	yes	.
Regula	50	yes	.
Regula	0	yes	.
Regula	50	yes	.
Regula	80	yes	.
Regula	40	yes	.
Regula	20	yes	.
Regula	35	yes	.
Regula	20	yes	.
Regula	20	yes	.
Regula	25	yes	.
Regula	30	yes	.
Regula	85	yes	.
Regula	40	yes	.
Regula	50	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	20	yes	45.4
Regula	50	yes	34.3
Regula	30	yes	38.4
Regula	80	yes	39.4
Regula	50	yes	39.7
Regula	50	yes	30.4
Regula	60	yes	26.5
Regula	80	yes	43.1
Regula	50	yes	33.3
Regula	40	yes	36.8
Regula	50	yes	41.6
Regula	50	yes	38.7
Regula	50	yes	37.4
Regula	50	yes	44.7
Regula	50	yes	33.4
Regula	30	yes	43
Regula	20	yes	40.7
Regula	80	yes	41
Regula	80	yes	36.6
Regula	70	yes	29
Regula	60	yes	30.4
Regula	50	yes	43.8
Regula	50	yes	40
Regula	30	yes	44.4
Regula	40	yes	40.5
Regula	70	yes	24.1
Regula	30	yes	43.7
Regula	10	yes	46.2
Regula	40	yes	41.5
Regula	30	yes	38.5
Regula	50	yes	39.1
Regula	60	yes	36.7
Regula	50	yes	39.4
Regula	50	yes	43.5
Regula	30	yes	40.5
Regula	50	yes	44.4

Regula	25	yes	45.8
Regula	30	yes	46.2
Regula	100	yes	39.3
Regula	50	yes	40.2
Regula	20	yes	39.2
Regula	50	yes	44.8
Regula	60	yes	44.2
Regula	80	yes	43
Regula	50	yes	41.2
Regula	70	yes	37.2
Regula	40	yes	38
Regula	10	yes	44.2
Regula	50	yes	40.7
Regula	60	yes	40.8
Regula	40	yes	44
Regula	50	yes	33.3
Regula	45	yes	35.5
Regula	50	yes	41.3
Regula	30	yes	40.8
Regula	50	yes	46.7
Regula	40	yes	41.7
Regula	50	yes	46.8
Regula	50	yes	45.3
Regula	50	yes	36
Regula	45	yes	46.7
Regula	45	yes	44.5
Regula	40	yes	45.3
Regula	30	yes	28
Regula	50	yes	45.7
Regula	50	yes	45.8
Regula	50	yes	45.2
Regula	50	yes	41.3
Regula	60	yes	41.2
Regula	20	yes	45.7
Regula	25	yes	38.5
Regula	40	yes	.
Regula	50	yes	.
Regula	40	yes	.

Regula	50	yes	.
Regula	35	yes	.
Regula	40	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	40	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	20	yes	.
Regula	40	yes	.
Regula	30	yes	.
Regula	10	yes	.
Regula	10	yes	.
Regula	45	yes	.
Regula	40	yes	.
Regula	80	yes	.
Regula	100	yes	.
Regula	100	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	70	yes	.
Regula	90	yes	.
Regula	40	yes	.
Regula	50	yes	.
Regula	60	yes	.
Regula	20	yes	.
Regula	80	yes	.
Regula	80	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	80	yes	.
Regula	40	yes	.
Regula	40	yes	.
Regula	60	yes	.
Regula	50	yes	.

Regula	50	yes	.
Regula	20	yes	.
Regula	30	yes	.
Regula	30	yes	.
Regula	85	yes	.
Regula	70	yes	.
Regula	50	yes	.
Regula	35	yes	.
Regula	40	yes	.
Regula	20	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	30	yes	.
Regula	50	yes	.
Regula	50	yes	.
Regula	1	yes	.
Regula	50	yes	.
Regula	30	yes	.
Regula	30	yes	.
Regula	10	yes	.
Regula	30	yes	.
Regula	30	yes	.
Regula	30	no	.
Regula	35	no	.
Regula	20	no	.
Regula	50	no	.
Regula	10	no	.
Abroad	10	yes	.
Abroad	15	yes	.
Abroad	10	yes	.
Abroad	90	no	.
Abroad	0	no	.
Abroad	5	no	.
Abroad	20	no	.
Abroad	0	no	.
Abroad	50	no	.
Abroad	0	invalid	.

Notes

typeofst = type of student (i.e., have studied abroad or not)

useofjap = percent of L1 respondents want NEST to use J in the L2 classroom

speakjap = Does respondent want a NEST who speaks J or not?

testscor = final test score of 1st-year Life Sciences department majors