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TOP-DOWN VERSUS BOTTOM-UP ANALYSES OF INTERLANGUAGE DATA

A Reply to Saito

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We are grateful to Hidetoshi Saito for his careful and reasoned critique of the VARBRUL procedure in his article, "Dependence and Interaction in Frequency Data Analysis in SLA Research" (this issue). Saito reanalyzes Young's (1988, 1991) study of *-s* plural variation in the English interlanguage of native speakers of Chinese. He raises two criticisms of the statistical analyses in the original work: (a) data from all participants were lumped together, resulting in an analysis that ignores possible variation across participants; and (b) interaction between independent variables was not investigated, whereas Saito finds that an interaction term contributes to a statistical model that fits the data better than the original analysis.

In this reply, written jointly by a linguist (Young) and a statistician (Yandell), we wish to argue that Saito's two points are valid but that they were both addressed in the design of Young's original research. In particular, we will show that the effects that Saito finds as a result of a purely bottom-up analysis of the numerical data emerged from Young's original analysis as a result of theory-based predictions. Our reply is in four parts. We begin by situating the VARBRUL procedure in its historical context at the time of the study in question. Second, we describe how VARBRUL enables the investigator to estimate the significance of across-participant variation and, if necessary, to include a participant factor as an independent variable in the analysis. Whether the investigator chooses to do this, however, depends on the theory of interlanguage variation that informs the study. Third, we respond to Saito's finding that the two independent variables of participants' ESL proficiency and

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preceding phonological environment interact by showing that this was, in fact, a hypothesis and a major finding reported in Young's study. Finally, we conclude with an evaluation of VARBRUL as a statistical method for the analysis of variation and suggest that more appropriate procedures are now available.

VARBRUL IN SLA: THE HISTORICAL CONTEXT

Before responding in detail to Saito's criticisms, some historical context to Young's study of variation in *-s* plurals is in order. Variation in SLA had been studied for at least 15 years previous to Young's study. Tarone (1988) reviewed a total of 75 studies of interlanguage variation, of which the earliest is Dickerson's (1974) dissertation study of Japanese learners' variable pronunciation of English /r/. Tarone reports three quantitative analyses that had been used in studies published before 1988: paired-samples *t* test, correlation coefficients, and analysis of variance for repeated measures. As can be seen from Tarone's descriptions, up until 1988, quantitative analyses of interlanguage variation had involved comparisons among a small number of (usually no more than two) variables. The limitations of these analyses were highlighted by Young (1991) in comparing three different researchers' analysis of variable tense marking in narratives. Wolfram (1985), Godfrey (1980), and Kumpf (1984) had separately analyzed the relationship between variable tense marking and episode boundaries (Godfrey, 1980), the surface form of the verb (Wolfram, 1985), and the back- or foregrounding of the event in the narrative (Kumpf, 1984). What is remarkable, in retrospect, is that all three researchers found support in their data for their own theoretical position and this suggested that the model of interlanguage variation adopted by these researchers—in which variation is attributed to a single cause—was inadequate. It is more likely that interlanguage variation is subject to the influence of not one but multiple contextual influences—a notion referred to later as the principle of multiple causes (Young & Bayley, 1996).

There were 10 factor groups in Young's study of *-s,* comprising 34 independent factors. This represented a departure from previous SLA studies of variation, not only because of the number of independent variables investigated but also because each factor group, as well as the dependent variable, was treated as a categorical variable. Each semantically plural NP, for instance, was coded for syntactic function as a subject, object, complement, or adverbial. Most previous studies had treated the dependent or the independent variables or both as continuous, hence the use of *t* tests and correlations.

One possible way of analyzing this categorical model is, as Tarone suggests, by means of ANOVA. However, in Young's (1991) study, this would have resulted in 46,080 possible combinations of factors, of which only 799 actually occur, leaving 45,281 cells empty in a multiple ANOVA. Although it is possible to consider only main effects and interactions in a multiple ANOVA, great care is needed with the imbalance in the number of observations per combination of factors (see Yandell, 1997). Furthermore, because the response is dichotomous, it makes more sense to consider categorical methods such as logistic regression. The same analytical problems—large numbers of independent factors and the distributional imbalances inherent in naturally occurring data—had been faced for a number of years by researchers working in the Labovian tradition of quantitative sociolinguistics. VARBRUL is a tool developed by mathematicians, computer scientists, and linguists to address those analytical problems (Pintzuk, 1988; Rand & Sankoff, 1990; Sankoff, 1988). It is a logistic regression analysis program that was developed specifically for the analysis of linguistic variation and has been used extensively by quantitative sociolinguists. In addition to algorithms for calculating regression coefficients (called "factor weights" in VARBRUL), standard error, and the goodness-of-fit of a model, VARBRUL has a heuristic module that a researcher can use in order to compare different models of variation by deleting or combining factors and factor groups. Full details of how to use the VARBRUL computer packages are given in Young and Bayley (1996).

Young's (1990) dissertation study, on which the 1988 article and the 1991 book were based, was among the first SLA studies to use VARBRUL. Adamson (1987) and Bayley (1991) were two other studies that appeared at about the same time. VARBRUL was used in the analysis because of the analytical advantages that it provided and because of its tradition of use in mainstream sociolinguistics.

THE EFFECT OF PARTICIPANTS

Now to Saito's criticisms. His first point is that Young lumped data from all participants together, resulting in an analysis that ignores possible variation across participants. Saito's reanalysis finds that participant is in fact a significant factor in accounting for the variation in *-s* plural—that is, the patterns of *-s* plural variation in the speech of some participants differ from the patterns in the speech of others. It is indeed true that participant was not included as a variable in Young's study. Nonetheless, using VARBRUL, it is quite straightforward to test whether interparticipant variation is a significant factor in the overall pattern of variation in the data: one simply constructs a factor group (an independent variable) that holds each of the 12 participants in the study. The significance of this factor group can then be tested by means of a step-up/step-down analysis.

The question of variation across participants is an important statistical and linguistic issue. One must be cautious in attempts to generalize from any sample to a larger population. The participants in this study were selected on the basis of their availability, which could bias inference to the larger community of Chinese learners of ESL. Setting that aside, we agree with Saito that it is important to adjust for participant differences. The simplest approach, as indicated by Saito, is to include participant as a fixed effect. If these participants were viewed as a random (albeit biased) sample from a larger population, then it would be appropriate to include participant as a random factor.

Interparticipant variation, however, is not only a statistical issue. The question of whether the pattern of variation in an individual's speech is similar to or different from the overall pattern of variation in a group of speakers is theoretically quite important and has been addressed in several studies. With respect to variation in a native-speaking speech community, Guy (1980) puts the question thus:

> Is variation in the speech community the result of the diversity of the group, reflecting the organization of society into a number of discrete lects within which variation is at a minimum, or is this variation present with identical uniform structures in the speech of every individual? (p. 2)

To answer this question, Guy (1980) investigated final /t/ and /d/ deletion in the speech of 13 native Philadelphians, 2 (native-speaking) immigrants to Philadelphia, and 3 New Yorkers. Participants ranged in age from 8 to 73 years and included both male and female speakers. Despite the interparticipant differences in locality, age, and gender, Guy found that final /t/ and /d/ deletion is in fact "a stable variable rule that is uniformly compelling on all speakers" (p. 34). The same variable was investigated by Bayley (1991) in his dissertation study of the English interlanguage of 20 adult Chinese speakers residing in California. Bayley concludes in a similar vein to Guy that "not only the order of constraints, but even their values remain stable across proficiency levels and individual speakers" (p. 109). Bayley found, however, that the factors influencing variation in interlanguage differed from those influencing variation in native speech.

Thus, from this limited evidence it appears that variation in final /t/ and /d/ deletion is stable across native-speaking speech communities and Chinese speakers of English as a second language. The marking of plural count nouns with *-s* in English is, however, a different kind of variable. There is no evidence that native speakers of the standard dialect vary in their deletion of *-s,* whereas there is abundant evidence that Chinese learners of English delete it. Thus, acquisition should involve reduction in the amount of variation. If the patterns of variation in *-s* plural marking differ from one Chinese learner of English to another, there is good reason to attribute that variation to differences in the overall proficiency levels of the speakers. And in fact, when participants' rates of *-s* plural marking are plotted against TOEFL scores as reported in Young (1993), there is a weak positive correlation. An additional reason for investigating the effect of proficiency on variation is Ellis's (1985, 1994) claim that initial acquisition of a variable form in interlanguage results in free variation that later resolves itself into systematic variation. Such a claim is easily tested by means of a VARBRUL analysis: The null hypothesis in such an analysis is that there is no systematic pattern of variation to be found in the data. If the null hypothesis is rejected, then variation is systematic.

Thus, in considering the contribution of participant to the model of variation in *-s* plural marking in Chinese-English interlanguage, the only theoreti-

Table 1. Comparison of participants' VARBRUL weights and TOEFL scores from Young's (1991) study of *-s* plural variation in the interlanguage of Chinese learners of English

Participant	TOEFL score	VARBRUL weight
Low proficiency		
Lily	270	0.25
Wendy	333	0.29
Mary	340	0.29
Norman	373	0.34
Pearl	403	0.34
Ai	407	0.35
High proficiency		
Qian	477	0.74
Jennifer	480	0.38
Chang	493	0.69
Rainbow	513	0.68
Gu	523	0.30
Sally	573	0.71

Note. VARBRUL weights are reported on a scale from 0.00 to 1.00 with greater weights signifying more frequent marking of *-s* on plural count nouns.

cally motivated hypothesis is that such contribution is due to interparticipant differences in proficiency. This is what Young (1991) tested. The first test was an analysis of the complete data set that included proficiency (as measured by TOEFL scores) as an independent variable. Participants' proficiency was revealed by this analysis to be a significant constraint on the production of *-s* plural, with high proficiency (TOEFL scores greater than 475) favoring production of *-s* more than low proficiency (TOEFL scores below 410). Additionally, as Young (1993, pp. 88–89) reported, there was a general trend for *-s* plural production to increase with proficiency. Following on the finding of a significant main effect for proficiency, an examination was done of the interaction of proficiency with other factors in the model. This was done by dividing data from the six high- and the six low-proficiency speakers into separate data sets and then analyzing each data set separately; the results of this analysis are described below in the section on "interaction among factors."

Could, however, the participant effect that Saito finds be attributed to some factor other than proficiency? This question is answered in a straightforward manner by reinserting a participant variable into the VARBRUL analysis and calculating the shared variance of the VARBRUL weights of each participant and their TOEFL scores. The original data from Young (1991) were thus recoded to include a participant variable and reanalyzed using VARBRUL. A step-up/step-down analysis in VARBRUL confirms Saito's finding that the new participant variable contributes significantly to the model of variation in *-s* ($p < .05$). The VARBRUL weights calculated for each participant were then compared with their TOEFL scores. As Table 1 shows, participants' TOEFL scores correlate quite well with their VARBRUL weights ($r = .721$, indicating 52% of shared variance). In fact, the rank order of VARBRUL weights mirrors participants' TOEFL scores in 9 out of 12 cases. The exceptions are Jennifer and Gu, whose proficiency is high but whose VARBRUL weights are low, and Qian, whose VARBRUL weight is higher than would be expected from his TOEFL score. We may thus conclude that much of the effect of participant on *-s* plural variation in this study can be attributed to proficiency, with increasing proficiency generally bringing with it increased *-s* plural marking. Given our hypotheses regarding acquisition of plural marking in English by Chinese learners, this is just what we expect. The remaining 48% of variance that is not shared by proficiency and participant is interesting but we, at least, have no theory to account for it: One would have to speculate as to the reasons why the behavior of Jennifer, Gu, and Qian is anomalous. In contrast, Saito's analysis stops at the point when he has identified participant as a significant factor—he provides no explanation for this finding. Here, we submit, is the essential difference between a theory-driven or top-down analysis and Saito's data-driven or bottom-up analysis. When an analysis is motivated by theory, then the results of the analysis either provide support for the theory or alternatively call it into question. As Long (1993) and others have stressed, theory-driven inquiry in a maturing field such as SLA is more systematic and organized than data-driven work; it gives us a sense that researchers are making some progress in tackling common problems instead of working in isolation to produce sets of unrelated findings. In this particular case, a theory-driven analysis has confirmed one facet of the acquisition of English regular plurals by Chinese learners: that learners' overall proficiency in English is a good predictor of their variation in *-s,* with higher proficiency learners producing more *-s* plurals and lower proficiency learners producing fewer.

INTERACTION AMONG FACTORS

We turn now to Saito's second criticism—namely, that an interaction between proficiency and preceding segment contributes significantly to the variation in plural. We agree and we are surprised that Saito should have missed this result in Young's published analysis, because it has been reported in two of the main textbooks in SLA (Ellis, 1994, p. 152, and Larsen-Freeman & Long, 1991, p. 87). As mentioned above, after finding that proficiency was a significant factor in accounting for variation in the *-s* plural data set, two separate analyses were carried out on high-proficiency and low-proficiency learners. This was done for two reasons. First, a separate analysis of low-proficiency learners was carried out in order to test Ellis's theory that initial acquisition of a variable form in interlanguage results in free variation that later resolves itself into systematic variation. According to Ellis (1994), the patterns of variation in the high- and low-proficiency learners should differ, with systematic patterns of variation emerging only in the high proficiency group. A second reason for performing separate analyses on high and low proficiency learners

Table 2. Factors that interact with proficiency and significantly affect variation in *-s* plural variation in the interlanguage of Chinese learners of English ($p < .05$)

Low proficiency	High proficiency
Preceding phonological segment	
Animacy (inhibits *-s* plural)	Animacy (promotes *-s* plural)
	Definiteness

Note. Adapted from Young (1991).

was the hypothesis that the phonological context of a variable form would interact with the speaker's proficiency and affect variation in *-s* because of lower proficiency learners' greater tendency to transfer phonological constraints from their L1—a prediction deriving from Major's (1987) ontogeny model of interlanguage phonology.

The results of the two separate analyses are shown in Table 2. The results show quite clearly that variation in the speech of low-proficiency learners is systematic but that the pattern of factors influencing variation is different for low- and high-proficiency learners. Specifically, three factors interact with proficiency: (a) The preceding phonological segment affects variation only in the speech of low-proficiency learners, (b) low-proficiency speakers tend not to mark plural animate nouns with *-s* whereas high-proficiency speakers do tend to mark plural animates, and (c) the definiteness of the NP affects variation only in the speech of high-proficiency learners. In contrast, Saito's reanalysis locates a single interaction between proficiency and preceding segment. The reason Saito fails to find the other two interactions may be because he analyzes the entire data set without splitting it into two proficiency levels—in fact, as Young found (1991, p. 144), the factor groups of animacy and definiteness are nonsignificant in the analysis of the combined data set of high- and low-proficiency learners.

Again, Young's original analysis differs from Saito's reanalysis because the original analysis and findings arose from theory-driven hypotheses regarding the possible effects of proficiency on patterns of variation. The original analysis did not support Ellis's (1994) claim that initial acquisition of a variable form results in nonsystematic variation and did provide partial support for Major's (1987) ontogeny model. In contrast, Saito's reanalysis is an ad hoc statistical study of the effect of interaction among the independent variables. By means of his data-driven analysis, Saito arrives at one of the same results as Young but misses the other two interaction effects of proficiency with animacy and with definiteness. The problem, we repeat, with such a data-driven analysis is that, even when the analysis produces statistically significant results, those results only have meaning in the unique context of the study that produced them. Instead, by designing a study in such a way that the investigator looks for results that confirm or challenge existing theories of second language acquisition, those results have meaning for the field in general. The results of theory-driven research can be compared with results from other studies designed within the same theoretical framework and either encourage or discourage acceptance of the theory.

BEYOND VARBRUL

We hope to have shown that, as an analytical procedure, VARBRUL is quite capable of dealing with the problems of dependency in frequency data and interaction among variables raised by Saito. Nonetheless, VARBRUL is a tool designed to handle a specific set of problems in language variation. Like many purpose-built tools, its proper and effective use depends on the skill of the user. Moreover, as the number of users is small, VARBRUL users often find themselves without support. Statistical consultants are mostly unaware of the procedure, and the people who originally designed and used VARBRUL are no longer available to answer users' questions. Moreover, the computer programs themselves are available only for the DOS and MacOS operating systems, not for Windows, with which most contemporary users are familiar, and the programs have not been updated since their releases in 1988 (the DOS version) and 1990 (the Macintosh version).

Fortunately, there is now a widely available statistical package that can perform many of the tasks of VARBRUL. Within the SAS/STAT software system, two procedures are available to perform logistic regression on non-normally distributed data: the GENMOD procedure (SAS Institute Inc., 1996, pp. 231–315) and the MIXED procedure (Littell, Milliken, Stroup, & Wolfinger, 1996). Although these procedures are not in themselves streamlined for linguists, they can be customized. The difference between the two procedures is that the GENMOD procedure handles models of variation in which participant (the speaker) is treated as a fixed effect, whereas MIXED treats participant as a random effect. GENMOD is thus appropriate to describe variation in a population of learners, whereas MIXED is appropriate when the speakers are randomly sampled from a larger population.

As an illustration, we have reanalyzed the *-s* plural data using the GENMOD procedure and included sample output in an appendix to this article. The GENMOD analysis parallels Young's (1991) VARBRUL analysis and the results reported in the appendix are comparable to the results reported by Young (1991, Table 15, pp. 144–145). The only differences in the two analyses are: (a) in the GENMOD analysis, we have included the speaker as an independent variable, whereas in the original VARBRUL analysis this variable was not included; (b) in the GENMOD analysis, we have investigated interactions between proficiency and the other variables; and (c) in the GENMOD analysis, we have tested the significance of each factor within a factor group, whereas in the original VARBRUL analysis only the significance of the factor group as a whole was tested. The GENMOD procedure analyzes the data set from Young (1991), namely, a binomial distribution of the dependent variable consisting of 1,565 tokens. This distribution is modeled by 1,021 different combinations of 11 explanatory variables. GENMOD performs a logistic regression on the data using logit as the link function. It outputs data that can be used to assess the goodness-of-fit of the model, estimates of the parameters of the model (these are comparable to the factor weights in VARBRUL), and likelihood ratio statistics for each independent variable. The GENMOD analysis confirms Young's original findings—specifically, that proficiency, noun position, syntactic function, preceding and following segments, and redundancy are significant factors in the model. It also confirms Saito's finding that there are significant interactions between proficiency and definiteness ($p < .05$), animacy ($p < .0001$), and preceding segment ($p < .001$). All other factor groups are nonsignificant at the .05 level. As an example of how GENMOD estimates parameters, we have included in the appendix the GENMOD output of the factors composing the factor group of preceding segment. The GENMOD analysis confirms Young's finding that the relative weight of the six factors in promoting *-s* plural is fricative > stop > vowel > nasal > sibilant > lateral; it finds, however, that stops and nasals are nonsignificant at the .05 level.

Given the general availability of the SAS/STAT software system, the flexibility of the GENMOD and MIXED procedures for handling problems of logistic regression of non-normally distributed data, and the comparability of results from these procedures with those output by VARBRUL, we recommend it as a tool for the quantitative analysis of interlanguage variation.

CONCLUSION

We would like to thank Saito again for challenging Young's original analysis of the *-s* plural data and thereby giving us this opportunity to revise and extend it. Saito's reanalysis was possible because the entire data set was published as an appendix to Young (1991). We firmly believe in the value of publishing data in addition to results so that future scholars can revisit the conclusions of the original study from a different theoretical stance and with more sophisticated tools for analysis. Researchers should, however, be aware that sophisticated analytical tools are mere servants of researchers' theories. The tools help us to answer questions that a theory has helped us to ask. Bottom-up analyses of interlanguage, no matter how sophisticated the tools of analysis, produce facts without a context in which those facts can be interpreted.

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APPENDIX

REANALYSIS OF YOUNG (1991) USING SAS: THE GENMOD PROCEDURE

Table A1. GENMOD output: Model information

Description	Value
Data set	YOUNG91
Distribution	BINOMIAL
Link function	LOGIT
Dependent variable	DVNUM
Dependent variable	DVTOT
Observations used	1565
Number of events	1021
Number of trials	1565

Table A2. GENMOD output: Class-level information

Class	Levels	Values
Interviewer	2	N n
Proficiency	2	H L
Definiteness	2	+ –
Animacy	2	+ –
Noun position	2	h p
Syntax	5	/ a c o s
Preceding segment	6	$ f l n s v
Following segment	3	# c v
Redundancy	5	n o p q ∅
Concord	5	/ a I p s
Speaker	12	A C G J L M N P Q R S W

Table A3. GENMOD output: Criteria for assessing goodness-of-fit

Criterion	DF	Value	Value/DF
Deviance	1507	1612.1764	1.0698
Scaled deviance	1507	1612.1764	1.0698
Pearson χ^2	1507	1647.8959	1.0935
Scaled Pearson χ^2	1507	1647.8959	1.0935
Log likelihood	—	–806.0882	—

Table A4. GENMOD output: Analysis of main effects and interactions

Source	DF	Chi-Square	Pr > Chi
Interviewer	1	0.1392	.7090
Proficiency	1	0.0000	.9997
Speaker (proficiency)	10	107.3046	.0001
Definiteness	1	0.4372	.5085
Animacy	1	0.0004	.9843
Noun position	1	10.8337	.0010
Syntax	4	40.0410	.0001
Preceding segment	5	29.7849	.0001
Following segment	2	7.7904	.0203
Redundancy	4	50.7233	.0001
Concord	4	2.3677	.6685
Interviewer × Proficiency	1	0.4753	.4906
Proficiency × Definiteness	1	4.1355	.0420
Proficiency × Animacy	1	18.1074	.0001
Proficiency × Noun position	1	0.0956	.7572
Proficiency × Syntax	4	4.8145	.3069
Proficiency × Preceding segment	5	22.1446	.0005
Proficiency × Following segment	2	0.2508	.8822
Proficiency × Redundancy	4	4.1914	.3807
Proficiency × Concord	4	5.8779	.2085

Table A5. GENMOD output: Analysis of parameter estimates for preceding segment

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > Chi
Preceding stop ($)	1	0.2181	.2741	0.6330	.4263
Preceding fricative (f)	1	21.4564	.5293	1643.2842	.0001
Preceding lateral (l)	1	–2.9997	.7905	14.3988	.0001
Preceding nasal (n)	1	–0.1916	.3145	0.3714	.5423
Preceding sibilant (s)	1	–0.9193	.4247	4.6847	.0304
Preceding vowel (v)	1	0.0000	.0000	—	—