
Statistics as a Second Language? A Model for Predicting Performance in Psychology Students

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Abstract

The purpose of this study was to test a model for predicting the performance of psychology students in statistics. Previous research in this area examined statistical performance in relation to three classes of variables: anxiety, attitudes, and ability. These variables are the essential components of an educational model developed by Gardner within the context of second language learning. It is argued that learning statistics is analogous to learning a second language, and that Gardner's model provides an integrative framework for understanding and predicting statistical performance. Measures assessing mathematical aptitude, math anxiety, and attitudinal and motivational variables were administered to volunteers from two introductory statistics courses in a psychology program. A causal model linking these variables was proposed and tested using a LISREL analysis. The results, which generally supported the model, are discussed in terms of their theoretical and practical implications.

Résumé

Le but de cette étude était d'évaluer un modèle pour la prédiction de la performance d'étudiants en statistiques. Les études antérieures ont examiné trois types de variables en relation avec la performance en statistiques: l'anxiété, les attitudes et l'habileté. Ces mêmes variables sont à la base d'un modèle d'apprentissage de langue seconde développé par Gardner. Il est possible que l'étude des statistiques soit analogue à l'apprentissage d'une langue seconde et que le modèle de Gardner soit utile pour la compréhension et la prédiction de la performance en statistiques. L'aptitude pour les mathématiques, l'anxiété envers les mathématiques, les attitudes et la motivation ont été évaluées chez des étudiants de psychologie qui prenaient un cours d'introduction aux statistiques. Un modèle causal reliant ces variables fut évalué avec une analyse LISREL. Les implications théoriques et pratiques des résultats de cette recherche sont discutées.

One of the most prominent courses for many students of psychology is the introductory statistics course. While undergraduate programs differ in the

number of methodological and statistical courses they require, virtually all of them have one course that involves basic descriptive and inferential statistics. The title of the course and its content may vary from program to program, but from the perspective of the student the course is commonly referred to by many as "stats" and by a significant minority as "sadistics". It is the latter perception that has led teachers to develop curricula designed to help students acquire an appreciation and understanding of the use of statistics in psychology (Dilbeck, 1983; Hastings, 1982; Greer & Semrau, 1984; Lovie & Lovie, 1973), and researchers to address the processes involved in learning statistics. In our experience, and that of other teachers (Hastings, 1982; Ray, 1962) it has been beneficial to conceptualize the learning of statistics as analogous to the learning of a language. In this paper the critical variables that have been examined by researchers studying the learning of statistics will be examined in a social psychological model of learning that has been developed within the context of second language learning.

The research examining factors contributing to the successful acquisition of statistical knowledge mirrors much of the research addressing the learning of other subject matters such as mathematics and second languages. Most of the variables that have been examined fall within three broad categories: anxiety, attitudes, and ability. We will introduce these variables separately, since only a few studies have looked at all three classes of variables in relation to performance in statistics (Adams & Holcomb, 1986; Feinberg & Halperin, 1978).

Anxiety

Any teacher of statistics can attest to the significant number of students experiencing apprehension with regard to their ability to perform well in the course. This anxiety most likely stems from the individual's history of performance and affective reactions in learning mathematics, and is present when the individual enters a university program. In fact, Betz (1978) found that "math anxiety" is experienced by a significant number of college students. In the case of a psychology sample, Betz found that at least one quarter of the students expressed considerable math anxiety, and that this was more evident for female than male students. She also found a negative correlation between math anxiety and mathematics achievement for female psychology students.

Math anxiety thus represents a potential stumbling block for many students enrolled in statistics courses, and a few studies have looked at the relationship between math anxiety and performance in statistics. Morris, Kellaway and Smith (1978) measured math anxiety using the Math Anxiety Rating Scale (MARS; Suinn, Edie, Nicoletti & Spinelli, 1972) in mathematics students and introductory statistics students in psychology, and found higher levels of math anxiety for those in psychology compared to those in mathematics. Furthermore, a higher level of math anxiety was significantly

related to poorer performance in statistics for the psychology students.

Adams and Holcomb (1986) also present evidence of a relationship between math anxiety and performance in statistics for a group of graduate majors in education and psychology. They found no significant relationship, however, between performance in statistics and traditional measures of trait and state anxiety (Speilberger, Gorsuch, & Lushene, 1970). Feinberg and Halperin (1978), on the other hand, found a small but significant relationship between the same measure of state anxiety and performance in statistics for a group of students who were primarily enrolled in liberal arts programs. They found no relationship, however, between performance and trait anxiety. In summary, math anxiety seems to be prevalent among psychology students and is a consistent predictor of their performance in statistics. Math anxiety also seems to be different from and more specific than general anxiety (Adams & Holcomb, 1986; Morris et al., 1978) and a better predictor of success in learning statistics than trait or state anxiety.

Attitudes

Most of the research examining attitudes in relation to statistics has been directed at test construction and validation. Two scales, the *Statistics Attitude Scale* (SAS: Roberts & Bilderback, 1980) and the *Attitude Towards Statistics* scale (ATS: Wise, 1985) have been developed. In validating these scales, attitude toward statistics has usually been found to correlate positively with scores in statistics courses (Roberts & Bilderback, 1980; Roberts & Reese, 1987; Roberts & Saxe, 1982; Waters, Martelli, Zakrajsek & Popovich, 1988; Wise, 1985). In addition to these core findings, Roberts and Saxe (1982) reported that students who performed better on a basic mathematics test and who had taken a greater number of mathematics courses had more favourable attitudes towards statistics.

While the scales specifically measuring attitudes towards statistics have been found to be related to performance in statistics, other more general attitude measures have not had the same success in prediction. Adams and Holcomb (1986) found no significant relationship between a mathematics attitude scale and achievement in statistics, while Feinberg and Halperin (1987) did. These mixed results suggest that a more specific measure of attitude may be a better predictor of behaviour, a result that is suggested by the work of Ajzen and Fishbein (1977) on the attitude-behaviour relationship.

Of final note in the Adams and Holcomb (1986) and Feinberg and Halperin (1978) studies is that their anxiety measures, which were predictive of performance, correlated significantly and negatively with their attitude towards mathematics measures. These results suggest that both attitudes and anxiety are interrelated affective measures involved in learning statistics.

Mathematical Ability

Although it is our belief that an understanding of statistics and its applica-

tions to psychological data does not require a sophisticated mathematical background, the relationship between mathematical ability and performance in statistics cannot be ignored. Both Adams and Holcomb (1986) and Feinberg and Halperin (1979) found significant positive relationships between performance in statistics and basic mathematical ability.

In addition to the direct influence that mathematical ability can have on the acquisition of statistical skills, it should also share an important relationship with math anxiety. Past experience with mathematics should be a significant participant in the etiology of math anxiety. In fact, a number of studies report significant relationships between mathematical ability and math anxiety, where individuals who have weaker mathematical skills demonstrate greater math anxiety (Adams & Holcomb, 1986; Betz, 1978; Suinn et al., 1972).

A model for predicting statistical performance:

Thinking of statistics as a second language

There are many theoretical models of educational achievement that offer general frameworks that can be applied to various educational subjects, including statistics (e.g., Bloom, 1976; Bruner, 1966; Carroll, 1963; Glaser, 1976). All of the variables deemed important by researchers addressing the learning of statistics (anxiety, attitudes, ability), however, are part of a more specialized socio-educational model that has been developed by Gardner (1979, 1981, 1985) in the area of second language learning. Gardner's model will be used as a basis for understanding the learning of statistics for two reasons. First, we believe that the conceptualization of statistics learning as language learning is both meaningful and fruitful. Furthermore, many of the measures developed by Gardner and his colleagues (Gardner, Clément, Smythe & Smythe, 1979) can be adapted to the statistics learning situation with some minor modifications, thus facilitating a test of the model that is to be proposed.

Ray (1962) wrote an introductory statistics textbook based on the premise that statistics represents the language of empirical science, and he develops this position by presenting statistical problems as either syntactical, semantical, or pragmatical. While it is of interest to discuss the linguistic similarities (and differences) between statistics and natural languages, our focus, within the context of Gardner's socio-educational model, is on their para-linguistic similarities. It is our view that the social factors involved in learning statistics are very similar to those involved in the acquisition of a second language (see Hastings, 1982 for a similar perspective). For example, both statistics and a second language are associated with a particular group of individuals who use them (e.g., the French vs. individuals who engage in empirical research), both involve new vocabularies that are foreign to the learner (e.g., "le plus-que-parfait" vs. "sampling distributions"), and both are capable of eliciting affective responses when they are spoken to an individual

learner (e.g., anxiety). A more detailed examination of Gardner's socio-educational model will serve to establish the parallel between statistics learning and second language learning.

In his basic model, Gardner (1979) identifies four individual difference variables that are expected to directly influence the degree of success a person will have in acquiring a second language: intelligence, language aptitude, situational anxiety, and motivation. It is obvious that intelligence will influence the extent to which any subject matter is learned, whether it be languages or statistics. It is the other three classes of variables that are of importance in this presentation. Language aptitude represents a specific ability involved in language learning; similarly, mathematical aptitude would be a special ability that should directly influence the understanding of the computational aspects of statistics. Given that measures of basic mathematical ability have been found to correlate with performance in statistics (Adams & Holcomb, 1986; Feinberg & Halperin, 1979), this seems to be a reasonable assertion.

Gardner (1979) has described situational anxiety as involving anxiety reactions that are evoked in situations involving the second language (e.g., being in the second language classroom or using the second language). Math anxiety is a form of situational anxiety that is expected to be aroused when a student is faced with the computational aspects of statistics, and past research has indicated that it correlates negatively with performance in statistics (Adams & Holcomb, 1986; Morris et al., 1978).

An important factor in Gardner's socio-educational model is that of the integrative motive. Gardner (1979, 1985) describes the motive as an attitudinal-motivational construct that includes not only the individual's motivation to learn the language, but also a number of other attitude variables involving the other language community and the language learning context. Gardner and his colleagues have developed a number of scales that measure these motivational and attitudinal variables (see Gardner, 1985) and found that they consistently predict second language performance (Lalonde & Gardner, 1985). Many of their studies have also combined these attitude and motivational measures into an *attitudinal/motivational index* which has proven to be highly predictive of grades, persistence in language study, and classroom behaviour (see Gardner, 1985). Similar variables have been shown to be operative in the acquisition of statistical knowledge (e.g., Roberts & Reese, 1987).

The applicability of Gardner's model to learning statistics seems to be very appropriate given the types of variables it includes in the prediction of performance. Furthermore, the basic structure of his model has received empirical support in a number of causal modeling studies (Gardner, 1983; Gardner, Lalonde & Pierson, 1983; Lalonde & Gardner, 1984).

There are, of course, some important differences between learning statistics and learning a second language. A crucial difference is that anxiety

probably plays a greater role in the prediction of performance in statistics than in that of performance in a second language. Math anxiety most likely begins to develop in childhood and although this anxiety may be dormant, it will be aroused when an individual begins a course in statistics. An important distinction, therefore, between Gardner's model of second language learning and our proposed model of learning statistics, is that Gardner's (1979) model treats situational anxiety as being independent from aptitude, while an inverse relationship between the two factors is predicted in the case of learning statistics. Situational anxiety is expected to be negatively related to mathematical aptitude if math anxiety is due in part to an individual's performance history in mathematics.

It is also expected that situational anxiety will be related to the attitudes and motivation that are involved in learning statistics, as well as to performance in statistics. This latter expectation has received some empirical support in research on second language learning (see Gardner, 1985).

Having combined the factors that have been studied in relation to learning statistics into a model, we will empirically examine these variables in relation to performance in statistics. Many of the variables will be measured by adapting some of the scales that have been developed by Gardner (1985). The three classes of variables (aptitude, situational anxiety, and attitudinal-motivational characteristics) will first be examined separately as correlates of performance. The variables then will be examined simultaneously in a preliminary test of a model for the prediction of performance in statistics.

METHOD

Subjects

The participants were psychology students from two sections of an introductory statistics course that spanned two semesters. Both sections were taught by the same instructor.¹ They were tested in the first week of classes in the first term and the second week of classes in the second term. The first testing session involved 91 subjects (19 males and 72 females) and of these subjects, 64 participated in the second testing session (11 males and 53 females). Attrition was due to one of three factors: students who dropped out of the course ($N = 16$), students who were not present in class for the second testing, or students who did not wish to participate in the second testing. No significant differences were observed between students who dropped the course and remaining students on any of the first session measures.

¹ The instructor was the first author of this paper. Considerable care was given in assuring a voluntary participation and anonymity in responses. For example, all questionnaires were identified only by student numbers and immediately put into a sealed envelope which was sent to the second author who was at another university.

Procedure

In their first week of classes, students were asked if they would participate in a study looking at different factors involved in learning statistics. Participation was voluntary and was not tied to course requirements in any way. Responses of the students were anonymous since questionnaires were sent to the second author who had no way of identifying participants with their student identification numbers.

In the first testing session in September students were given a brief questionnaire consisting of certain anxiety and attitudinal measures, followed by a mathematics test and a few demographic questions (Variables 1,2,3,5). The second session in January involved a questionnaire consisting of a fixed random order of items assessing all of the anxiety and attitudinal/motivational measures (Variables 3,4,5,6,7,8,9). In order to debrief participants as to the nature of the research, they were presented with preliminary results in the last month of classes.

Materials

All measured variables are described below. Cronbach alpha indices of internal consistency reliability were calculated for the anxiety, attitude and motivation measures and are reported following each of these measures. For variables that were measured at both sessions, test-retest correlations are given in addition to alpha coefficients. The anxiety and attitude items were accompanied by 7 point Likert type scales ranging from *Strongly Disagree* to *Strongly Agree*, unless otherwise indicated. The theoretical construct that is being tapped by the different measures is briefly described before they are presented.

Two measures were taken in order to assess an individual's mathematical aptitude. While neither of these measures are pure measures of aptitude, it is believed that they are indicative of an individual's ability in mathematics.

1. *Mathematics Background.* Subjects indicated at what grade levels they had taken mathematics courses from four options starting at lower levels of high school up to a university level. Higher scores indicate a higher level of educational attainment.

2. *Basic Mathematical Ability.* A ten item test developed at the university to help psychology students decide if they needed to work on their basic skills in mathematics was administered. The types of problems given include rounding, computation, transformation of percentage to decimal, basic graph interpretation and solving worded problems. Higher scores indicate better mathematics skills.

Two measures were taken to assess situational anxiety. The measure of number anxiety was given at the beginning of the course since it was believed that students would have had sufficient experience in dealing with numbers for this construct to be accessible. The measure of statistics anxiety was given only in the second term, when students would have had enough experience to evaluate this specific type of anxiety.

3. *Number Anxiety*. Three positively worded and three negatively worded items were developed in order to assess the degree of uneasiness associated with doing calculations. Responses were coded such that higher scores reflect greater anxiety. The correlation between the first and second testing scores was .86. (Cronbach α : time 1 = .89, time 2 = .87).²

4. *Statistics Anxiety*. Five positively worded items were developed in order to assess the degree of anxiety experienced by the student when doing statistics. Most of these items were adapted from Gardner et al.'s (1979) *French Use Anxiety* measure. A higher score indicated a greater level of anxiety ($\alpha = .83$).³

Five measures were taken to assess certain aspects of the attitudinal/motivational component involved in learning statistics (i.e., an approximation of Gardner's integrative motive). Only one of these measures was given in the first session, namely Attitude towards Statistics in Psychology, which was developed specifically for this study. All students would have received some exposure to statistics in their introductory psychology course and would have some attitude concerning their use in psychological research. All other scales used items that were adapted from measures developed by Gardner and his colleagues (see Gardner, 1985).

5. *Attitude towards Statistics in Psychology*. Five positively worded and five negatively worded items were combined to determine an individual's attitude concerning the importance of statistics in psychology. Responses were coded so that a higher score would reflect the belief that statistics are an essential aspect of the field of psychology. The correlation between scores from the first and second testings was equal to .50. (α : time 1 = .80, time 2 = .80)

6. *Attitude towards Learning Statistics*. Five positively worded and five negatively worded items were combined to determine an individual's attitude concerning the experience of learning statistics. Most of these items were adapted from Gardner's (1985) *Attitude towards Learning French* scale. Responses were coded so that higher scores reflected greater enjoyment in learning about statistics. ($\alpha = .91$)

7. *Motivational Intensity*. This measure consisted of 7 multiple choice items designed to measure the intensity of a student's motivation to learn statistics.

² There was a small but significant drop in the level of number anxiety from the first testing session ($M = 23.12$) to the second session ($M = 21.61$) ($t(65) = 2.44, p < .05$). It should be noted that the computational aspects of the course in the first term were relatively simple and most of the students probably realized that they had the ability to handle them.

³ In terms of its predictive validity, the statistics anxiety measure has proven to be more effective than the MARS, a general measure of math anxiety. Pepe (1990) found the statistics anxiety measure to have a significant negative relationship with measures of statistical performance, while the MARS did not correlate significantly with these same measures of performance.

Most of these items were adapted from Gardner's (1985) measure of motivational intensity. A high score indicated a greater degree of effort being spent in learning statistics. ($\alpha = .63$)

8. *Statistics Course Evaluation.* Ratings on 10 semantic differential scales were summed to reflect the student's general evaluative reaction to the course (Gardner, 1985). A high score indicated a more favourable evaluation. ($\alpha = .91$)

9. *Statistics Instructor Evaluation.* Ratings on 10 semantic differential scales were summed to reflect the student's general evaluative reaction to the instructor (Gardner, 1985). A higher score indicated a more favourable evaluation. ($\alpha = .89$)

A number of measures were combined in order to evaluate the student in the course. The measure of Assignments is considered to be an index of effort, whereas all other measures are indicative of performance. Exam scores are broken down by term in order to facilitate the interpretation of results.

10. *Assignments.* Throughout the course of the year students were asked to hand in weekly assignments. This work was not graded in terms of its correctness. Students were simply given a mark for having completed the work on time and a small portion of the final grade was awarded for completing these assignments. The purpose of this procedure was to create an incentive for students to keep up with their work. A high score indicated the student was doing considerable work in the course.

11. *Quizzes.* Ten quizzes were given throughout the year during tutorial sessions. A quiz typically involved one problem solving question. An average score was calculated for the nine quizzes on which a student received the best grades.

12. *First term exams.* Two exams were given in the first term and combined into a single score. These exams involved multiple choice, short answer and problem solving questions.

13. *Second term exams.* Two exams scores, including a final integrative exam, were aggregated into a single measure.

14. *Final Grade.* The final grade was the result of a weighted combination of variables 10 through 13.

RESULTS

Reliability analyses

An inspection of the Cronbach alpha reliability coefficients presented in the methods section reveals good internal consistency for the anxiety and attitude measures (alphas ranged from .80 to .91), considering the number of items used to assess each scale (from 5 to 10 items). The alpha coefficient for the Motivational Intensity measure was relatively low ($\alpha = .63$), and may have been due its limited number of items and the restricted variability provided by a multiple choice response scale.

There were test-retest reliabilities for two of the measures for the four month period between the two testing sessions. Number Anxiety maintained

a good reliability across time ($r = .86$) suggesting that this type of anxiety was well developed and stable across time. The test-retest reliability for the student's Attitude towards Statistics in Psychology was much weaker ($r = .50$) however, and may suggest that the student attitudes were not sufficiently developed at the beginning of the course to provide a stable measure across time.

Gender differences

The scores of male students were compared to those of female students on all of the variables that were assessed, as previous research had indicated greater math anxiety for female psychology students compared to male students (Betz, 1978). It was found that males had taken more mathematics courses than females ($M = 2.89$ vs. $M = 2.40$, $t = 2.19$, $p < .05$), expressed less number anxiety than females at the time of the first testing ($M = 19.42$ vs. $M = 23.96$, $t = 1.94$, $p < .06$), and scored lower than females on the measure of statistics anxiety ($M = 13.18$ vs. $M = 17.91$, $t = 2.12$, $p < .05$). Only one gender effect was found on performance measures: males scored significantly higher than females on quizzes ($M = 8.63$ vs. $M = 7.96$, $t = 2.12$, $p < .05$).

Correlational Analyses

Pearson product moment correlations were computed between the various predictor variables and the measures of performance. The resulting correlations are presented in Table 1. There are two points to consider when attempting an interpretation of these results. First, the measure of *Assignments* is not a measure of achievement but a measure of the amount of effort that the student is putting into the course. Second, most of the anxiety, attitude and motivation measures were taken after the first term exams.

It can be seen in Table 1 that the two indices of mathematical aptitude, namely mathematical background and mathematical achievement, were fairly consistent correlates of performance in statistics, particularly exam performance. Neither of these mathematics measures correlated significantly with the number of assignments completed by the student.

The pattern of relationships between the anxiety and performance measures was very similar to the pattern observed between the mathematical aptitude and performance measures. The measures of number anxiety and statistics anxiety, which were administered mid-way through the course, correlated significantly negatively with exam performance in both the first and second terms. Neither of these measures correlated significantly with the number of assignments completed. It should be noted that the measure of number anxiety administered at the beginning of the academic year did not correlate significantly with any of the performance measures.

The correlations between the attitude/motivation measures and performance are particularly interesting. Two of these measures, course evaluation and motivational intensity, correlated significantly with the number of

TABLE 1
Correlations between hypothesized correlates of statistics performance and measures of performance

	Assignments	Quizzes	First Term Exams	Second Term Exams	Final Grade
Math Background	.18	.35**	.19	.36**	.37**
Math Achievement	.00	.14	.36**	.29*	.29*
Number Anxiety 1	.07	-.02	-.18	-.16	-.14
Number Anxiety 2	-.14	-.21	-.40**	-.40**	-.40**
Statistics Anxiety	-.19	-.31*	-.49**	-.45**	-.48**
Attitude Statistics in Psychology 1	.09	.26*	.14	.28*	.30**
Attitude Statistics in Psychology 2	.11	.27*	.33**	.22	.30*
Course Evaluation	.34**	.34**	.40**	.34**	.41**
Instructor Evaluation	.00	-.12	-.16	-.09	-.10
Attitude Learning Statistics	.24	.11	.28*	.15	.21
Motivation	.39**	.23	.25	.31*	.32*

Note. The minimum number of cases used in the computations of correlations was 75 for measures from the first testing session, and 59 for measures from the second session (except for Motivation which had a minimum of 54). Two tailed tests of significance were used.

** $p < .01$ * $p < .05$

assignments completed. In addition, the attitude that the student had about learning statistics correlated marginally with the number of completed assignments ($r = .24$, $p < .06$).

The most consistent attitudinal correlate of performance was the student's evaluation of the course which was significantly related to all performance measures. The student's evaluation of the instructor, on the other hand, was not related to any of the performance measures. Generally speaking, the relationships between the attitudinal-motivational variables and performance were not as strong as the relationships that were observed between the performance measures and the mathematical aptitude and situational anxiety measures.

Causal modelling analysis

In order to examine the relationships of the different predictor variables with each other and with performance, a LISREL (Jöreskog & Sörbom, 1984) causal modelling procedure was used. This procedure permits an assessment of the degree to which the observed relationships in a set of variables (i.e., correlations) fit a theoretical network of relationships. In the present case, the theoretical model to be tested was the adapted version of Gardner's socio-educational model of second language acquisition presented in the introduction.

Twelve of the measured variables in this study were used as indicators of five latent variables. The hypothesized relationships among these latent variables comprise the structural or theoretical model to be tested. In the present case, one of the five latent variables was treated as exogenous (Mathematical Aptitude) and the remaining four were treated as endogenous (Situational Anxiety, Attitude-Motivation Index, Effort, and Achievement). It was hypothesized that Mathematical Aptitude would be a direct positive cause of Achievement and a negative cause of Situational Anxiety, which in turn would be a cause of both the Attitude-Motivation Index and Achievement. Moreover, the Attitude-Motivation Index was predicted to be a determinant of Effort, and Effort was expected to lead to Achievement.

The measurement model links the measured or indicator variables to the latent variables. As conceived, Mathematical Aptitude was assessed by the measures of Mathematical achievement (MACH) and Mathematics history (MHIST), while Situational Anxiety was assessed by the measures of Statistics anxiety (STANX) and Number anxiety 2 (NANX). The Attitude-Motivation Index was represented by four variables, Attitude toward Statistics 2 (ATST), Statistics Course Evaluation (COUR), Attitude toward Learning Statistics (ALST) and Motivation (MOT). Effort was assessed in terms of one measure, Assignments (ASS). The final construct of Achievement was seen to be assessed by three variables, the two exam scores from the second term (EX1 and EX2) and Quizzes (QUIZ). The variables in the measurement model were selected in order to preserve the integrity of time in the causal sequence (e.g., the first term exam scores were omitted because they were obtained before the attitude and motivation measures).⁴ The correlation matrix which served as the input for the LISREL analysis is presented in Table 2.

Figure 1 presents the causal model that best fits the correlations among the variables. It can be seen in Figure 1 that the measurement model fits the data well. All of the factor loadings of indicator variables on their latent variables were significant. All of the hypothesized paths presented in Figure 1 are significant. The one hypothesized path that did not result in a substantial (nor significant) coefficient was the path linking Situational Anxiety to Achievement. The final model was one that had Mathematical Aptitude as a negative predictor of Situational Anxiety and a positive cause of Achievement, Situational Anxiety as a negative influence on an individual's Attitude-Motivation Index which in turn had a positive effect on Effort which leads to Achievement.

The various indicators of the extent to which the model fits the correlations among the variables were all acceptable. The Chi-square value for the

⁴ The Statistics Instructor Evaluation measure was omitted from the analysis because of a ceiling effect and a resultant restriction in variability. These same problems were probably the reason why this variable was such a poor predictor of performance in the correlational analyses.

TABLE 2
Correlations matrix used as input for LISREL analysis

	MACH	ATST	NANX	STANX	AIST	MOT	COUR	EX1	EX2	QUIZ	ASS
MHIST	.45	.06	-.43	-.38	.17	-.07	.20	.05	.37	.18	.11
MACH	—	.10	-.52	-.40	.16	-.10	.24	.38	.38	.15	-.05
ATST		—	-.49	-.40	.58	.16	.56	.21	.21	.27	.16
NANX			—	.72	-.62	-.21	-.61	-.37	-.36	-.17	-.15
STANX				—	-.52	-.44	-.51	-.29	-.44	-.26	-.21
AIST					—	.42	.83	.19	.17	.13	.27
MOT						—	.37	.31	.29	.24	.39
COUR							—	.33	.34	.35	.35
EX1								—	.66	.55	.38
EX2									—	.57	.37
QUIZ										—	.62

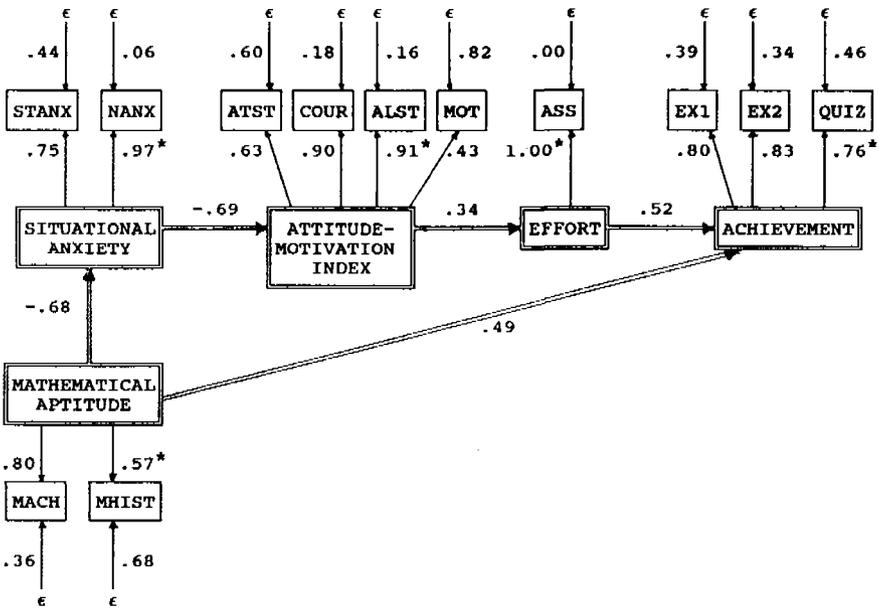
model was 84.89 with 50 degrees of freedom. Although this was significant at the .002 level, the ratio of chi-square to degrees of freedom is only 1.70, which is well below the value of 5.00 that is viewed by Wheaton, Muthen, Alwin and Summers (1977) as indicating a reasonable fit. Furthermore, the goodness of fit index for the model was 0.82, and the root mean square residual was only 0.10. The distribution of modification indices and first order derivatives similarly indicated that no other modifications of the model would result in any further significant paths or correlations in the structural model, or improvements in the measurement model.

Because it was initially hypothesized that there would be a causal path from Situational Anxiety to Achievement, a number of attempts were made to force this path. To do so, however, required that the path from Mathematical Aptitude to Achievement be eliminated, and when this was done, the model did not fit the data as well as the present one. The present model, therefore, represents the most reasonable fit of the data that were obtained.

DISCUSSION

The results of the present study have both theoretical and practical implications for psychologists interested in the learning and teaching of statistics. Some of the theoretical issues that can be addressed with our data and certain issues for future research will be outlined. In addition, suggestions will be made with regard to intervention programs designed to help students experiencing difficulties with the statistical courses in our curricula. Finally, teaching strategies that have been found to be effective for second language learning will be considered in terms of the teaching of statistics to psychology undergraduates.

All three classes of variables that have been examined in past research relating to statistics learning (i.e., aptitude, anxiety and attitudes) correlated with measures of performance in introductory statistics. The present results support the findings of studies such as the one by Feinberg and Halperin



* The scale was set by fixing these values in the analysis. They were standardized in the final solution.

Fig. 1 A causal model for the prediction of achievement in statistics.

(1978), who have probably conducted the most comprehensive study of students learning statistics. These studies, however, have failed to examine all of the critical variables simultaneously within any type of theoretical framework. The results of the causal modelling analysis testing our proposed model, therefore, are of particular interest.

For example, past research suggested that situational anxiety would be directly related to achievement in statistics (Adams & Holcomb, 1986; Morris et al., 1978). The LISREL analysis revealed, however, that a direct path between situational anxiety and achievement was not significant when the path between mathematical aptitude and achievement was present. This result is consistent with findings obtained by Llabre and Suarez (1985) who studied a group of introductory algebra college students who were not majoring in a mathematics related field. They found that a measure of math anxiety did not significantly improve the prediction of grades after controlling for mathematical aptitude in a path analysis. We disagree with their conclusion, however, which stated that math anxiety has little to do with performance once the math anxious student has enrolled in a course. Our results suggest that anxiety can still have an indirect impact on performance because of its effect on different attitudes and motivation which influence the amount of effort the student exerts in learning statistics.

In addition to demonstrating the potential pattern of relationships among variables involved in learning statistics, the present results indicate that

Gardner's (1979, 1981, 1985) socio-educational model of second language acquisition can be applied profitably to the issue of studying statistics, although the model was modified to suit specific features of the statistics situation. While Gardner (1979) viewed situational anxiety and aptitude as being independent from one another in the context of second language learning, these two variables are seen as being negatively related to each other in statistics learning. The analogy of statistics as a second language was beneficial, therefore, since it provided a framework for understanding the interplay of variables involved in the process of learning statistics.

There are some limitations in the present study which should be considered in terms of the generalizability of the present findings and in terms of future research. Gender differences were obtained on some of the measured variables, and it was not possible to determine if the final causal model would be identical for males and females. The present study provides a preliminary test of a model that needs further testing with different samples in order to test its replicability across samples and gender. Other researchers may want to hypothesize alternative models having different patterns of relations among the variables and compare the adequacy of those models to the one examined in this study.

One of the practical implications of the present results has to do with intervention programs for helping students having difficulties in statistics. A variety of interventions can be used to help psychology students who have problems coping with statistics: reducing math anxiety, increasing mathematical competence, or a combination of these strategies. The present results suggest that focussing on mathematical skills may be just as effective as focussing on anxiety management, given the direct impact that mathematical ability can have on performance in statistics. While it is unreasonable to expect any program to increase an individual's mathematical aptitude, it should be possible to create a short series of workshops directed at mastering the basic mathematical skills involved in introductory statistics (e.g.'s, rounding, factorials, order of operations in computation, basic algebraic manipulations, strategies in problem solving). If an effective program can be established, we would predict improved performance not only because of better computational and problem solving skills, but also because of a reduction in anxiety that should accompany such a mastery. We do not, on the other hand, recommend that students with difficulties be required to complete a college level mathematics course, since such a strategy may serve to increase the student's anxiety given the evaluative nature of such courses.

With regard to teaching statistics, the present results indicate the value of offering students an incentive for completing their assignments. In this study, the measure of a student's effort was the number of assignments that were completed throughout the year. The causal modelling analysis indicated that the student's effort had a direct and positive impact on performance. It is recalled that assignments for these students were non-evaluative in that

points were given for having tried to complete an assignment on time, and not for getting the correct answers to problems. By using such a strategy, the student is reinforced for working because a small component of the grade is a function of this work, yet this work does not involve the pressure that can be brought about by traditional evaluations.

Finally, why is it beneficial to view statistics as a second language when it comes to teaching? By applying the analogy, we can borrow certain teaching strategies that have been found to be effective with second languages. A popular and successful teaching strategy for second languages is the immersion program (e.g., Genesee, 1984). In many of these programs the second language is used as the major medium of instruction for a variety of subjects; as a result the second language is no longer a discrete subject matter but a daily tool of instruction. While it is impossible to teach undergraduates psychological concepts using only statistical terminology, it is possible to use some statistical language in most psychology courses. For example, when a research study is presented in a psychology course the instructor can spend some time talking about the research design that was adopted, the type of data that was collected, the statistical procedure that was used to test the hypothesis, and the statistical meaning of the results (i.e., what is meant by a significant difference). Furthermore, it is possible to create simple research projects in courses other than statistics, where students collect their own data and do their own analyses. A common observation among upper level undergraduates and graduate students is that they feel they are truly getting a grasp of statistics when they are working at analyzing their own data. This experience parallels that of immersion in a second language and suggests that all efforts should be made to integrate the language of statistics into the general curriculum and not keep it neatly categorized as "that horrible requirement that I need for my degree".

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