ESTIMATING RELIABILITY UNDER A GENERALIZABILITY THEORY MODEL FOR WRITING SCORES IN C-BASE

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

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Presented by Ze Wang

A candidate for the degree of Master of Arts

And hereby certify that in their opinion it is worthy of acceptance.

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Chapter 1

Introduction

Reliability is a statistical measure of accuracy in mental assessment. The more a measure is reliable, the greater its precision. Obviously, then, the reliability of a test is an essential concern of test developers and users. According to the *Standards for Educational and Psychological Testing* (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1985), obtaining and reporting evidence concerning reliability and errors of measurement are fundamental responsibilities of test developers and publishers.

Readers may be already familiar with the reliability conceptions in classical test theory (CTT). Under CTT, an observed score consists of a true score and an error score; and, then, reliability is a measure of the agreement between the observed and the true scores. The concept of reliability approached in CTT can be depicted as the consistency among trials. The statistical representation of reliability in CTT is the proportion of observed score differences that are due to true differences in the attribute being measured. There are different methods of estimating reliability such as test-retest reliability, alternate forms, inter-rater reliability, internal consistency, etc. Each method of reliability estimation addresses one source of error (that is, the discrepancy between the observed score and the true score).

These CTT concepts, however, are extended in modern approaches to reliability appraisal, specifically Generalizability theory (G theory). G theory is a much more psychological approach to measurement than is assessment under CTT. In this approach, an individual's "latent traits" are what interest test developers and users. A latent trait is an underlying ability and represented a cognitive process, such as reading or reasoning. Given a sample of test items to appraise the latency, the question G theory tries to answer is how well those items represent the universe of all possible items which are appropriate indicators of the particular latent trait being measured. Under G theory, test developers and test users are concerned with the accuracy of generalizing from a person's observed score to the average score that person would have received under all the possible conditions that the test user would be equally willing to accept. Unlike CTT, G theory can extract variances from different sources. In other words, G theory takes into consideration different sources of error simultaneously. Those different sources are multidimentional facets. With the statistical assistance of factorial ANOVA, G theory decomposes the observed score difference and analyzes the variances of those facets.

G theory does not supercede or negate CTT. More accurately, it can be viewed as an extension of CTT. The *universe score* in G theory is analogous to the true score in CTT. Both theories tap the systematic variation in the population of test-takers. Errors are assumed to be independent of true scores and uncorrelated. G theory also assumes that the samples selected (of persons, raters, items, etc.) and used to estimate the error variances comprise random samples from their respective populations (http://www.measurementexperts.org/learn/theories/theories_gt.asp). Reliability (in CTT) and generalizability coefficients (in G theory), as indicators of how dependable a test is, are joint characteristics of the test and examinee groups. Population-specific as they are, those coefficients are not just a characteristic of a test. Just as the norming group should be representative of the targeted population in the CTT world, the universes of admissible observations should be defined in advance in the G theory domain.

A brief comparison between CTT and G theory is depicted in Figure 1.

<Insert Figure 1 About Here>

Two kinds of study are distinguished in G theory: Generalizability (G) studies and Decision (D) studies. The purpose of a G study is to provide information about sources of variation in measurement; it is usually associated with the development of a measurement procedure. A D study is to use the information from G studies to design the best application of the measurement for a particular purpose.

Applying G theory in the assessment of students' writing ability is important in that different aspects (facets) of individual score differences can be quantified and used in future decision making.

College Basic Academic Subjects Examination, (*College BASE*) is a nationally standardized achievement examination of general education skills. According to the test manual, *College BASE* is a diagnostic, criterion-referenced, achievement test (Osterlind & Merz, 1990). It evaluates knowledge and skills in English, mathematics, science, and social studies, usually after a student completes a college-level core curriculum. *College BASE*, with emphases on concepts and principles derived from course materials, is developed to accurately assess students' academic progress. It bridges generalized aptitude tests for college entrance and specialized department exams. Not only does it assess basic and enduring knowledge in each of the four subject areas, but also it provides performance rankings in higher order thinking skills, namely, interpretive, strategic and adaptive reasoning abilities. In addition to testing general academic knowledge and skills in campus-wide assessment programs, *College*

BASE also serves as an exam to qualify individuals for entry into teacher education programs (Assessment Resource Center, 2005).

The four subjects are the four broadest domains in *College BASE*. And then, from broadest to most specific, there are four tiers: subjects, clusters, skills and enabling subskills. There are altogether four subjects, nine clusters and twenty-three skills. A long form of *College BASE* consists of 180 multiple-choice questions and one essay prompt, which is supposed to test one of the English writing skills.

Three writing skills are identified and tested in *College BASE*: Skill 104 (Understand the various elements of the writing process, including collecting information and formulating ideas, determining relationships, arranging sentences and paragraphs, establishing transitions, and revising what has been written), Skill 105 (Use the conventions of standard written English), and Skill 106 (Write an organized, coherent, and effective essay). Skills 104 and 105 are tested in the form of multiple-choice questions.

The introduction of G theory to the analysis of those multiple-choice writing items will help detect the sources of score variances, and adds to the reliability and validity evidence of the writing cluster in *College BASE*.

This study appraises the reliability of writing scores in *College BASE* by both traditional methods and G theory. They are appropriately contrasted. Another purpose of this study is to examine the consistency between multiple-choice questions and essay writing in *College BASE*.

Chapter 2

Literature Review

Reliability Appraisal

The reliability of a test is the extent to which the test yields consistent scores. In addition to the classical test theory, there are other modern methodological approaches to reliability estimation, among which are G theory and IRT.

In CTT, each observed score is comprised of a true score and an error score which is a random variable, independent of true scores and uncorrelated with each other. The true score model in CTT looks like this: $X = T + E$, where X is the observed score, T the true score and E the error.

The true score in CTT is determined by the amount of attribute being measured that the test taker has. It is a person's true ability that underlies responses to a test. The error score is the difference between a person's observed and true scores. It represents measurement error. Measurement error comes from many different sources. On the part of the examinee, there are errors from physical condition on the day of the test, fluctuation in memory, test anxiety, etc. On the part of test administration, there are errors from deviation from standard directions, environmental conditions, poor relationship between tester and examinee, and so on. Besides, there is also an error related to test construction, such as content sampling error or ambiguity of wording of items. If the test includes subjective scoring, there is another error from test scoring. All those sources of error affect the observed scores and result in loss of reliability of a test.

In MacMillan's (2000) brief comment on CTT, he describes:

> One is operating within classical test theory if one (a) speaks of the reliability of a test with a common standard error of measurement for all test takers, (b) accepts that the measure of a person is simply the total score of mean score of that person on a particular test, or (c) believes that the only way individuals can be compared across different test forms is to have equivalent test forms.

MacMillan (2000) further mentions that reliability in CTT is defined as a ratio of true score variance to observed score variance and techniques related to CTT include linear scaling or equating and regression.

Despite numerous potential sources of error, classical reliability theory doesn't differentiate the error term and acts as if there is only one single error source. The true score model represented in the "variance" world looks like this: $\sigma_X^2 = \sigma_T^2 + \sigma_E^2$. That is, the variance of the observed scores is decomposed into the true score variance and the error variance. The reliability coefficient of a test is the ratio of σ_T^2 to σ_X^2. Conceptually, reliability implies how closely an observed score approximates an individual's true score. The methods used in classical reliability analysis include test-retest reliability, interrater reliability, internal consistency, etc. Among them, internal consistency measured by Cronbach's coefficient alpha or Kuder-Richardson formula 20 is the most seen in literature of classical reliability.

From the definition of reliability in CTT, we can see that a reliability coefficient tends to be higher if the test is associated with larger true score variance. Therefore, factors affecting a reliability coefficient include group homogeneity, range of item difficulty levels, test length, etc. If the examinee group is more heterogeneous, the items are at various difficulty levels, and the test is longer, the reliability of the test tends to be higher. The term indicating the magnitude of measurement error is standard error of measurement (SEM) of a test. The SEM of a test in classical reliability theory is the same for all people.

G theory was first introduced by Cronbach and colleagues in response to the limitations of CTT (1963, 1972). The attractive characteristic of G theory is that it investigates and analyzes multiple sources of error with one design.

In G theory, the observed score has more components. For example, in an achievement test, an individual score on a particular item is affected by a persons effect (systematic differences among people's achievement, or *object of the measurement*), an items effect (variability due to item difficulty), and a residual including the person-by-item interaction (the difference in ordering of students on different items due to the educational and experiential histories that students bring to the test (Shavelson & Webb, 1991, pp.5-6)). An observed score for one individual on one item can be stated as:

$$X_{pi} = \mu + (\mu_p - \mu) + (\mu_i - \mu) + (X_{pi} - \mu_p - \mu_i + \mu) \quad (1)$$

The first term on the right-hand side of the equal sign is the grand mean in the population and universe. The grand mean is constant for all people (and has no variance). The second term designates a persons effect, the third an items effect, and the last the residual effect involving the interaction and all other sources of error not identified in this design. The last three terms are random effects and have a distribution. Statistically, we can prove that the expected value of μ_p is equal to μ .

The variance of those X_{pi} scores can be decomposed corresponding to the above equation.

$$\sigma^2(X_{pi}) = \sigma^2(p) + \sigma^2(i) + \sigma^2(pi,e) \quad (2)$$

That is to say, the variance of observed scores can be partitioned into independent sources of variation due to differences among persons, items, and the residual term which includes the person-by-item interaction.

IRT, sometimes called latent trait theory, is another modern test theory (opposed to CTT). IRT is to evaluate the degree of precision and breadth of scales that are used to measure latent constructs, or underlying traits of concepts that are not directly observable and must therefore be measured indirectly. It is a psychologically based theory of mental measurement that specifies information about latent traits and characteristics of stimuli (e.g., test items and other appraisal exercises) used to present them (Osterlind, 2005).

Both G theory and IRT are more psychological approaches to measurement than CTT. However, they are fundamentally different. The G theory approach is still observed score analysis like CTT, while IRT separates the people and item characteristics and is therefore sample-free. On the other hand, IRT requires strong assumptions such as unidimensionality and local independence. Those are not required in G theory.

Lee and Frisbie (1999) compared four reliability estimation methods for test scores composed of testlets using empirical data. Those four approaches were: stratified coefficient alpha, Cronbach's alpha, IRT information function, and a G coefficient. Their main purpose was to investigate the appropriateness and implication of using a G theory approach to estimating the reliability of scores from tests composed of testlets. The magnitude of overestimation using Cronbach's alpha based on item scores in estimating the reliability of test scores composed of testlets was about 0.04 relative to the testlet approach with G theory. "Local dependence" arising from items having a common stimulus results in overestimation of reliability of scores in a similar way when using IRT approaches. Lee and Frisbie (1999) also contrasted the Cronbach's alpha approach and the G theory approach in terms of confidence intervals. Although the confidence interval for the true score using the generalization coefficient was slightly wider than that using Cronbach's alpha based on item scores, the difference was small that it is not likely to lead to serious misinterpretation of the scores in a practical sense.

MacMillan (2000) in his study dealing with large sparse data sets used the CTT, G theory and multifaceted Rasch model (an IRT model) approaches to detecting and correcting for rater variability. Those approaches were compared. Both the CTT and multifaceted Rasch indicated substantial variation among raters. However, the rater variance component with the G theory approach suggested little rater variation.

Generalizability Theory Overview

G theory is a conceptual approach to measurement that focuses on understanding how well the components of a particular assessment occasion represent their domain (Osterlind, 2005). Shavelson & Webb (1991) define generalizability theory as a psychometric theory of dependability of behavioral measurements. In their book, *Generalizability theory: A primer*, Shavelson & Webb (1991) introduced basic concepts and statistical model underlying G theory. Examples of G studies with crossed, nested, and fixed facets were presented. D studies and generalizability coefficients were explained and compared. This book provides a good introduction to G theory and is easy to understand. Complicated mathematical and statistical formulas were avoided so that readers could have a general picture of G theory without digging too much into calculations behind it.

Generalizability theory by Brennan (2001a) is by far the most complete description of G theory. In this book, Brennan describes the relationships among G theory, factorial ANOVA and CTT by saying that CTT and ANOVA are parents of G theory. Examples of different designs are throughout the book. On the part of calculation are how different variance components constitute mean square errors, how the degrees of freedom for each facet are calculated, how different error terms come into play, etc. This book is divided into three sets of chapters in terms of complexity of the topics. The first set contains fundamentals of univariate generalizability theory. They are sufficient to perform many G analyses as well as to understand most literature on G theory. The second set is about statistical complexities and more advanced topics in univariate theory such as the variability of estimated variance components and unbalanced designs. The third set is devoted to multivariate G theory, where each object of measurement has multiple universe scores. Covariance components in addition to variance components should be considered in a multivariate G analysis. G theory is also contrasted to other advanced measurement theories such as IRT in Brennan's book.

Swartz et al. (1999) listed three reasons that G theory is important for writing assessment. First, G theory enables researchers to simultaneously estimate the magnitude of multiple independent sources of error variance. Second, the partitioned estimated variance components can be used to carry out Decision studies. Third, G theory allows the estimation of test score reliability based on whether the scores will be used to make relative or absolute decisions. That is, G theory allows for different ways of calculating reliability for different decision-making purposes. While CTT assumes relative use of test scores, G theory expands CTT in the sense that how reliable the scores are depends on the use of those scores. G theory is not only a theory that looks into reliability, but also it has an element of the validity of test scores.

In summary, G theory enables the analyst to isolate different sources of variation in the measurement and to estimate their magnitude using the analysis of variance (Shavelson & Webb, 1991, pp.14-15). The variance components estimated in G study can be used in future applications of the measurement.

Universe of Admissible Observations and Facets

From the perspective of G theory, a measurement is considered as a sample from a universe of *admissible* observations. An admissible observation is one that the decision maker is willing to accept as interchangeable with other admissible observations for the purpose of making a decision (Shavelson & Webb, 1991, p.3). The *universe* of admissible observations is defined in terms of sources of variation, or *facets*. The universe can have one single or more than one facet. Each facet has conditions. “Facets” and “conditions” in G theory are similar to the concepts of “factors” and “levels” in an experimental design. For example, in a G study design of an achievement science test, items is a possible facet. Each item in the test can be considered as a condition of this facet. An individual’s score on an item is an observation. If the decision maker (test developers and users) decides that each item is a sample from a universe of items that are acceptable to test the latent construct, the variation associated with the facet items can be estimated.

Suppose we have the entire universe of items and all those items are tested on an individual. The mean score of those scores is the *universe score* of that person (μ_p).

The variance of the universe scores over all persons in the population is the universe score variance (Brennan, 2001a, p.10). When we develop a measurement of a latent trait, we want as much (proportion) as possible variance is due to the universe score variance, and little variance due to facets or residual.

G studies and D studies

A distinction is necessary to make between Generalizability studies (G studies) and Decision studies (D studies) in G theory. The purpose of a G study is to identify and decompose the observed score variance into different sources. Whatever the sources are depend on the definition of the universe of admissible observations. As many as possible potential sources of variation should be included in a G study. The purpose of a D study is to use the variance decomposition from G study to design applications of the measurement for particular purposes. In other words, G studies are usually associated with the development of a measurement procedure, while D studies use information from G studies and apply the procedure. Gao and Brennan (2001) compared the two kinds of studies in their study of variability of estimated variance components and related statistics in a performance assessment. A G study focuses on the magnitude of sampling variability arising from distinct sources in a universe of admissible observations. A D study collects new data by selecting new samples of the measurement procedure from a prespecified universe of generalization and new samples of objects of measurement from the population. The accuracy of variance component estimates impacts estimation and interpretations of measurement error variances and generalizability coefficients. Also, the estimated variance components are subject to sampling variability. Researchers should be aware of sampling variability that affects the precision of estimating variance components in G and D studies.

When applying the results from a G study to a D study, one important question is what kind of decision is to be made. Is it going to be a relative decision or an absolute one? For a relative decision, people are to be rank ordered or assigned percentiles. In contrast, for an absolute decision, an estimate of individuals' universe score is to be obtained for the purpose of screening or selection. With an absolute decision, a person's universe score is irrelevant to other people's universe scores.

Generalizability Coefficient and Index of Dependability

Generalizability coefficient in G theory is analogous to the reliability coefficient in CTT. It is the ratio of universe score variance to the expected observed-score variance. The expected score variance includes both the universe score variance and the relative error variance. The formula for Generalizability coefficient is appropriate when making a relative decision.

In the former scenario of achievement test with items as the only facet, the relative error is

$$\sigma_{rel}^2 = \frac{\sigma_{pi,e}^2}{n_i} \qquad (3)$$

where n_i is the number of items in the measurement. This is true because $\sigma_{pi,e}^2$ in Equation 2 is the error variance for a *single* item. The amount of error for an instrument is inversely proportionate to its number of items.

The formula for calculating Generalizability coefficient is:

$$\rho^2 = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_{rel}^2} \qquad (4)$$

The G coefficient shows how accurate the generalization is from a person's observed score, based on a sample of the person's behavior, to his or her universe score (Shavelson & Webb, 1991, p.14). It reflects the proportion of variability in individuals' scores that is systematic and attributable to universe-score.

If an absolute decision is to be made, *index of dependability* is the proper coefficient to be used. Index of dependability is the ratio of universe score variance to the sum of universe score variance and absolute error variance.

$$\phi = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_{abs}^2} \tag{5}$$

In calculating ϕ, not only the residual variance (interaction and unidentified error) but also the items variance contributes to the absolute error.

In the former scenario of achievement test,

$$\sigma_{abs}^2 = \frac{\sigma_i^2 + \sigma_{pi,e}^2}{n_i} \tag{6}$$

The difference between relative and absolute decisions is reflected in how the relative and absolute errors are calculated. Relative error only involves interactions that include the persons effect (object of measurement). In contrast, absolute error involves all variances except for the universe score variance. This difference is easy to depict with the Venn diagram in Figure 2.

<Insert Figure 2 About Here>

Both generalizability coefficient and index of dependability involve n_i, therefore, we can determine how many items are needed in a measurement in order to reach a particular ρ^2 or ϕ. Here is when D studies come into play.

Random and Fixed Facets

A facet can have an infinite number of conditions in the universe or a finite number of conditions in the universe but not all conditions are included in a measurement design. In this case, the facet is a *random* one. The conditions in a particular measurement design are a sample of all possible conditions. On the other hand, a measurement can exhaust all possible conditions of a facet in a G study and therefore the facet is a *fixed* one. There is no variance component for a fixed facet in a G study. Statistically, G theory treats a fixed facet by averaging over the conditions of the facet. Shavelson & Webb (1991) points out that "if it does not make conceptual sense to average over the condition of a fixed facet, or if conclusions about such average are of little interest, separate G studies should be conducted within each condition of the fixed facet." (p. 67).

Crossed and Nested Facets

When all conditions of one facet are observed with all conditions of another source of variation, the design is a *crossed* design. In our simple scenario where each individual responds to all the items in the achievement test, the design is a crossed one and can be denoted by $p \times i$. In a G study design, it is also possible that one facet is *nested* within another. Nesting happens when two or more conditions of the nested facet appear with one and only one condition of another facet (Shavelson & Webb, 1991, p.11). For example, items in a test may be nested within the subtests facet when each subtest has two or more distinct items. The notational form of this design is $p \times (i : t)$, where t represents the facet subtests.

MacMillan (2000) in his study with large, sparse data sets gave a good example of how to come up with an efficient and practical design.

Chapter 3

Research Design and Methodology

This study seeks to understand proper reliability interpretation in two aspects of writing appraisal in collegians. The aspects are writing skills assessed by multiple choice items and writing skills by a judged writing sample. Collectively, these two appraisals compose a thorough evaluation of a student’s proficiency in commonly-used written communication. This study appraises the reliability of writing scores in *College BASE* by both traditional methods and G theory.

The two multiple-choice skills in the Writing cluster of *College BASE* test related but distinct English writing abilities. Skill 104 is to understand the various elements of the writing process, including collecting information and formulating ideas, determining relationships, arranging sentences and paragraphs, establishing transitions, and revising what has been written. Skill 105 is to use the conventions of standard written English. One purpose of the study is to examine the relationship between the two skills. It is hypothesized that the two skills correlate but not highly with each other.

The second purpose of this study is to decompose the variance of the observed scores into three sources: the persons effect, the items effect, and the interaction between them (confounded with error). Comparing those variance components, we would be able to see how much variance in the observed scores is due to differences among people’s characteristics and how much due to items and interaction. If people differences contribute a lot to the variation in the observed scores (a large persons effect), this test discriminates examinees well.

In this study, skills is treated as a fixed facet, within which items are nested. The GENOVA application program (Crick & Brennan, 1983) will be used to conduct data analysis. We could either conduct one univariate G study with items nested within skills, or conduct one univariate G study for *each* skill. Shavelson and Webb (1991) made some recommendations about how to choose between the two alternatives (p.67).

The examinees are required to write an essay at each administration of *College BASE* (Skill 106). Another purpose of this study is to examine the consistency between multiple-choice questions and the essay question in the Writing cluster of *College BASE*. If there is a lack of consistency, reasons for this inconsistency would be explored.

Skills 104 and 105 in the Writing Cluster of *College BASE* consist of 8 multiple-choice items each. Classical reliability analysis can be carried out on those items to evaluate the consistency of responses by examinees to each item. A fourth purpose of this study is to compare statistics from the G study to those from a classical reliability analysis.

Research Design and Statistical Methods

This study design is a quantitative one. Three different analytic methods are used in this design. Correlational analyses are used to examine the relationships among the three writing skills. Means and correlation coefficients for different gender and ethnic groups are compared.

A generalized analysis of variance study (G study) is conducted to decompose the variance of the observed multiple choice scores. Using GENOVA developed by Dr.

Brennan (1983), the researcher attributes the variance of the observed scores to four sources: the persons effect (*p*), the items effect (*i*), the interaction between persons and items (*pi*), and the error effect (*e*). Since the last two sources are confounded with each other and indistinguishable, the total observed variance is decomposed into three parts. As a follow-up step of this variance decomposing, the percentage of total variance from each effect is calculated to examine the influence of the persons effect, items effect and their interaction.

Finally, a classical item analysis is conducted to examine the item characteristics and detect potential poor items. Item characteristics include item difficulty levels, item discrimination indices and alphas if item deleted. The scale alpha from the classical item analysis is compared to the generalizability coefficient from the G study.

Data Source

Data used in this study were from a standard test administration of *College BASE* on April 4th, 1999. This administration of the test was for teacher education certification. A total of 1923 booklets were distributed. After deleting those with missing values on those 16 multiple-choice writing questions, there were altogether 1522 cases left. Of them, 1155 (75.9%) took *College BASE* for the first time. Out of consideration of a more homogeneous group, only those 1155 observations were analyzed in this study. The final sample consisted of 1045 (90.5%) Whites, 62 (5.4%) Blacks, 17 (1.5%) Hispanics, 13 (1.1%) Asian/Pacific islanders, 3 (0.3%) American Indians/Alaskans, and 15 (1.3%) examinees unclassified by ethnicity. There were 880 (76.2%) females and 273 (23.6%) males in this sample, with 2 (0.2%) with missing values on gender. According to the year in school, 91 (7.9%) were freshmen, 586 (50.7%) sophomores, 339 (29.4) juniors, 96 (8.3%) seniors, 12 (1.0%) graduate students, and 31 (2.7%) unclassified.

The first two writing skills were tested with 8 multiple-choice questions for each skill. In this study, a correct response to a multiple-choice question was coded as “1” and an incorrect response coded as “0”. All the multiple-choice questions were computer scored. The third writing skill assessed by a writing sample was rated on a 0-6 point scale by at least two professional evaluators familiar with college-level writing. Those essay readers are trained to evaluate the essay as a whole (Assessment Resource Center, 2005). Only one score for the writing sample was given on the score report for the examinee. Examinees’ responses and scores were stored in an SPSS dataset.

The scoring of the writing sample is guided by the following rubric (excerpted from *College BASE Brochure*, 2005, p. 7):

> **Score of 6:** Essays assigned a “6” will be excellent in nearly all respects, although the circumstances under which the essays were written allow for some imperfections. The “6” essay should employ a sound organizational strategy with clearly developed paragraphs proceeding from a sharply focused and clearly identifiable main idea or thesis. Assertions should be sufficiently developed and directed to engage the specified audience and should be supported through appropriate examples, details, and/or other fully integrated rhetorical techniques (e.g., analogy, narration). Again, considering the writing situation, there should be few, if any, distracting grammatical and mechanical errors.
>
> **Score of 5:** Essays assigned a “5” will be good, but not excellent, in almost all respects. Specifically, look for a thesis or main idea that is clearly discernible and for sophisticated reasoning and/or support, going well beyond the information provided by the prompt. The writer will engage the opposition, beyond a passing reference, and may even redefine the problem while not evading it. A “5” may be marred by some stylistic and/ or organizational problems, or it may be well-organized and fairly sophisticated at the sentence level but fail to use or fully integrate a variety of rhetorical devices. There

should be few distracting grammatical and mechanical errors.

Score of 4: Essays assigned a "4" will present a competent thesis and adequate organization and will acknowledge the opposition, even if that acknowledgment takes the form of an indictment. A "4" may rely heavily on the prompt for ideas but supply sophisticated examples, or it may present ideas beyond the prompt but offer scant or predictable support. An essay which shows some insights but fails to unite them may also receive a "4." Generally, a "4" may contain a few distracting grammatical and mechanical errors, although essays appreciably damaged by major errors should not receive a "4."

Score of 3: Essays assigned a "3" will contain some virtues, although they may contain an unengaging or poorly focused main idea or thesis or be marred by inadequate development. A "3" might, for example, express some ideas that reflect a thoughtful consideration of the problem, but at the same time be obscured by unclear or "incorrect" writing. On the other hand, it might represent clear and competent writing but convey superficial ideas, or ideas which fail to account for information provided in the prompt. A "3" may be primarily a list of responses to the prompt, but with some development of the listed ideas, or it may show an organizational strategy which goes beyond listing, but offers support only in list form. As an argumentative essay, it may exhibit specious or circular reasoning or lack the coherence necessary to foster a complete understanding of the writer's meaning. A number of major and distracting grammatical and mechanical errors may place an otherwise thoughtful and well-written essay in this category.

Score of 2: Essays assigned a "2" are weak because they are poorly written throughout (with consistent errors in grammar or mechanics), or because they fail to support major points, or because they are exceedingly superficial. A "2" may be flawed by a lack of unity or discernible organizational pattern, or it may rely upon a clearly organized list with little or no development or simple development which presents personal examples as proof.

Score of 1: Essays assigned a "1" will be clearly unacceptable as college-level writing or will demonstrate an only momentary engagement with the topic, concentrating instead upon some tangential concern(s). A "1" will be riddled with major grammatical and mechanical errors and/or will consist of a collection of random thoughts or undeveloped ideas. In short, essays that appear to have been written in careless haste or without effort should receive a "1."

Score of 0: Essays that for any reason cannot be read should be assigned this score.

Chapter 4

Results

Correlational Analysis

One-Way ANOVAs were carried out to examine the differences in the three writing skills between the two gender groups. The means and standard deviations of the skills for each group and for the combined group are shown in Table 1.

<Insert Table 1 About Here>

The means and standard deviations for both gender groups were similar on all of the three skills. The biggest difference between the male and female groups was .20 and appeared in Writing Conventions. Results from One-Way ANOVAs showed that none of these differences in means was significant (*p*s>.05).

The correlations among the three writing skills for the two gender groups and the combined group are displayed in Tables 2, 3 and 4.

<Insert Table 2 About Here>

<Insert Table 3 About Here>

<Insert Table 4 About Here>

The correlations among the three writing skills were not high, ranging from .234 (between Writing as a Process and Essay for males) to .396 (between Writing as a Process and Writing Conventions for males). This may be due to the fact that the three skills, though under the same umbrella of “English writing”, test related but distinct (sub)abilities. The same latent construct of writing ability underlying an individual’s responses to the questions manifests itself differently when the indicators (test items hereof) test different contents. On the other hand, it is necessary to differentiate different writing skills since they do reflect different aspects of the same latent trait.

When scores for different ethnic groups were looked at, the results were somewhat interesting. The means and standard deviations for ethnic groups of the three writing skills are shown in Table 5.

<Insert Table 5 About Here>

Means for different ethnic groups differed more dramatically than for different gender groups. In fact, Post Hoc tests indicated several significant differences. All the significant differences involved the Black group. However, if we keep in mind the demographics of the dataset, the results may be due to the severely unequal sizes of different ethnic groups. The vast majority of the test takers were Whites (90.5%). With severely unequal sample sizes, it may not be valid to conclude significant differences in the populations.

The correlation coefficients among the three skills for different ethnic groups are represented in Tables 6, 7, 8 and 9. The correlation coefficients for the American Indians/Alaskans group are not listed since the cell size was too small (N=3).

<Insert Table 6 About Here>

<Insert Table 7 About Here>

<Insert Table 8 About Here>

<Insert Table 9 About Here>

The correlations seem to vary drastically for different ethnic groups. There are both positive and negative correlations. Again, we should keep in the mind the sample sizes of those ethnic groups. For example, the correlation is perfect between Writing Conventions and Essay Writing for the American Indians/Alaskans group (not listed here). Nonetheless, there were only 3 people from this group. One can be almost sure that this correlation is bogus due to the extremely small sample size. The negative correlation between Writing Conventions and Essay Writing for the Asian/Pacific Islander group (-.594) may be questionable too since there was only 13 individuals from this group. The correlation coefficients for the two biggest groups (Black and White) are all positive, significant and not high (ranging from 0.216 to 0.496). The results are similar to when looking at different gender groups.

The empirical distribution of the essay writing scores is displayed in Table 10.

<Insert Table 10 About Here>

The majority of the people (884 out of 1155) got an essay writing score of 3 on a 0-6 scale. The distribution of essay scores is bell-shaped. Nobody got the highest (6) or the lowest possible (0) score. The fact that no one out of 1155 got a score of 6 may indicate that the scoring is too stringent or this group of test-takers is rather homogeneous in their essay writing ability.

Generalized Analysis of Variance

There were three facets in the Generalizability analysis of this study: persons, items and skills. Since all the items were presented to all the examinees, this is a crossed design. In addition, items were nested within skills, according to how those multiple-choice items were constructed. Therefore, the complete design in this G study is denoted as: $p \times (i : t)$, where *p* refers to the persons effect, *i* the items, and *t* the skills.

Shavelson and Webb (1991) suggested a procedure for G studies dealing with fixed facets. Based on their suggestions, the researcher could choose to conduct either one $p \times (i : t)$ study including the two skills or one separate $p \times i$ study for each skill. The first step of their procedure is to treat all facets as random and then examine the variance components associated with the fixed facet. The GENOVA control cards for this analysis are in Appendix A. The results are shown in Table 11.

<Insert Table 11 About Here>

From Table 11, the main effect for skills was negative and set to zero, indicating no difference between the two skills. Examinees performed similarly in both skills. Large negative variance estimates are indication of misspecification of the measurement error. However, small negative variance estimates can be set to zero, as recommended by Shavelson & Webb (1991).

The interaction between persons and skills was also very small ($\sigma^2_{pt} = 0.0024022$, only 1.1% of the total variance). These indicated that the two skills did not differ in substantial ways, which was supported by the significant positive correlation between the two skills ($r(1153) = .392, p < .05$, see Table 4). According to recommendations by Shavelson and Webb (1991), the following G study was based on a single

$p \times (i : t)$ design, with *t* (skills) as the fixed facet. Appendix B includes the GENOVA control cards for this design. Results of the analysis are shown in Table 12.

<Insert Table 12 About Here>

The differences between items were small ($\hat{\sigma}^2_{i*} = .0097177$, 4.5% of the total variance). A moderate amount of total variance (8.2%, $\hat{\sigma}^2_{p*} = 0.0176265$) was due to people difference. The large residual component (87.3% of the total variance) indicated large differences in the relative standing of examinees on different items, large unmeasured variation, or both. This also included random error.

The variance component for persons (0.01766265) accounted for 8.2% of the total variance in scores. This was the variance component for universe scores and indicated that persons systematically differed in their writing ability. The variance component for items was small, both relative to the other components and in an absolute sense. The square root of $\hat{\sigma}^2_{i*} = .0097177$ was about 0.10. Assuming normality, the expected range of item means was about 0.40 (4 times the square root of variance). This range was moderate compared to the range of item scores (0 to 1). Again, the variance component for the residual $\hat{\sigma}^2_{pi:t,e*} = .1875921$ (87.3% of the total variance) showed that a substantial proportion of the variance was due to the interaction between persons and items and/or other unsystematic or systematic source of variation that were not measured in this study.

The Generalizability coefficient in this G study can be calculated using Equations 3 & 4. Since the true variances are always unknown, those estimated variance components from the GENOVA analysis are plugged in. The calculations are shown below.

$$\hat{\rho}^2 = \frac{\hat{\sigma}_p^2}{\hat{\sigma}_p^2 + \hat{\sigma}_{rel}^2} = \frac{\hat{\sigma}_p^2}{\hat{\sigma}_p^2 + \hat{\sigma}_{pi:t,e}^2 / n_i} = \frac{0.0176265}{0.0176265 + 0.1875921/16} = .6005$$

This indicates that about 60% of the variability in individuals' scores was systematic and attributable to the universe score. This interpretation is similar to that for the reliability coefficient in CTT since CTT concerns the relative standing of individuals.

The index of dependability is

$$\hat{\phi} = \frac{\hat{\sigma}_p^2}{\hat{\sigma}_p^2 + \hat{\sigma}_{abs}^2} = \frac{\hat{\sigma}_p^2}{\hat{\sigma}_p^2 + (\hat{\sigma}_i^2 + \hat{\sigma}_{pi:t,e}^2 / n_i)} = \frac{0.0176265}{0.0176265 + (0.0097177 + 0.1875921)/16} = .5884$$

This coefficient should be used when absolute decisions are to be made using this measurement.

Classical Reliability Analysis

Skill 104 in the Writing Cluster of *College BASE* is comprised of 8 multiple-choice items that are constructed to test people's understanding of the various elements of the writing process. Skill 105 in the Writing Cluster of *College BASE,* consisting of 8 multiple-choice items, is to test people's use of the conventions of standard written English. Classical reliability analysis can be carried out on those items to evaluate the consistency of responses by examinees to each item. First, classical reliability analysis was conducted on each skill and then on the 16 items altogether. Several item-total statistics were checked during each analysis. Those statistics include corrected item-total correlation (also called item discrimination index, it is a point bi-serial correlation between the item and the total score), squared multiple correlation, and alpha if item deleted, along with an overall alpha level for the whole analysis. The overall alpha is actually Cronbach's alpha. It is an index of internal consistency of a test.

The results from the reliability analysis for Skill 104 (Writing as a Process) indicated an overall alpha of .3484. Item 3 seemed not to be functioning consistently among the population since it had a very low item-total correlation (.0882) and the overall alpha would increase from .3484 to .3486 if it were to be deleted from the scale. However, this should not be overinterpreted, since single item typically correlates with total test very low. Researchers have long noted the classical unreliability of single test items (Thurstone, 1937)

The results from the reliability analysis for Skill 105 (Writing Conventions) indicated an overall scale alpha of .5191. No item in this skill seemed to be really bad. The item-total correlations ranged from .1508 to .2825. The overall alpha would decrease if any item were to be deleted.

The results from the reliability analysis for both skills combined suggested an overall alpha of .5978. Again, Item 3 seemed to be poorly fitting. Its item-total correlation was .0975 in this case. The overall alpha would increase to .6038 if it should be deleted.

The overall alphas from all the three reliability analyses are rather low. This may be due to the fact that too few items were included in the analyses (only 8 multiple-choice items in each skill). In classical test theory, longer tests tend to be more reliable. It is evident that the overall alpha for the combined analysis was greater than each separate reliability analysis for each skill.

The overall alphas from the above reliability analyses were Cronbach's alphas, testing internal consistency. Now, comparison can be made between Cronbach's alpha for the combined reliability analysis and the generalizability coefficient from the G study. We can see that they are very close. The Cronbach's alpha is .5978 while the generalizability coefficient is .6005. Actually, our G study design $p \times (i:t)$ with items as the only random facet and skills as a fixed facet is very similar to the classical item analysis. The G study extracted the variation due to the items facet, whereas the traditional method regarded this variation as part of the error term.

The advantages of G theory over the classical reliability theory would be more obvious when more than one random facet is involved. Besides, results from G studies can applied to D studies to make relative or absolute decisions.

Chapter 5

Discussion

Overview of Results

The purpose of this study is to understand proper reliability interpretation with both the traditional method and generalizability theory, using data from *College BASE*. The coefficients are comparable for the 16 multiple-choice writing items, using classical reliability analysis or generalized analysis of variance. About 60% of the observed-score variance in those multiple-choice items is due to the object of measurement in this study, the persons effect. The universe score variance (in the sense of G theory), or the true score variance (in the sense of classical reliability theory) accounts for about 3/5 of the total variance of the observed scores. Although a reliability of 0.6 seems not high for an entire instrument, the fact that more than half of the observed-score variance is from the object of measurement is adequate reliability evidence with only 16 multiple-choice items.

Results from the G study indicated that the variation due to persons was small ($8.2\%, \hat{\sigma}^2_{p*} = 0.0176265$). However, there are two ways to explain this. First, the variation due to persons effect was almost twice the variation due to the items effect ($\hat{\sigma}^2_{i*} = .0097177$, 4.5% of the total variance). Compared to the differences among items, the differences among people are more prominent in this study. The test is to find people differences in the latent trait of writing ability. Therefore, the larger the variation is from people differences, the better and more effective the test is. Second, the residual component from the G study was very large ($\hat{\sigma}^2_{pi:t*} = 0.1875921$, 87.3% of the total variance). This residual term is the error variance (including interaction between persons and items, unmeasured variation, and random error) for a *single* item. Since single items typically correlates with the total test very low, it is not surprising to see large variation associated with them. If relative error of an effect is to be calculated, the error variance for a single item should be divided by the number of items.

The skills effect was considered as a fixed facet since the variation due to skills was zero. Although the correlation between the two multiple-choice-item skills is not high, G study shows that they were still testing the same thing. Comparing with variation due to persons and items effects, the contribution of skills to the observed-score variance is negligible.

Importance of Current Study

This study is important for two reasons. First, it examines reliability by two means—traditional and modern—and contrasts them, in the context of appraisal by multiple-choice items combined with assessment via a direct sample of composition. As mentioned, however, there is decided emphasis upon reliability estimation by modern means (i.e., G-theory).

Another uncommon aspect to the study is the sample used for the appraisal: collegians. While there is manifold study of appraisal of elementary and secondary students, it is uncommon to study a college-level group. Since, more than half of all high school graduates attend some form of post-secondary education, it is important to study this population as a group with unique and important characteristics.

Studying the variance of scores for them will help educators and other decision makers realize significant features about them.

In addition, this study adds to the reliability evidence of *College BASE*. As an established achievement examination of general education skills, *College BASE* was developed using the advanced measurement technique of Item Response Theory (IRT). Applying G theory to *College BASE* provides more information about this test itself and more accurate understanding of how people's writing ability differ.

Limitations of Current Study

The biggest limitation is that this study is not an experimental one. With this secondary dataset for this study, the researcher was unable to define during the design stage her universe of admissible observations and carry out a more complete G study. Besides the object of measurement (persons effect), there was only one other random facet (items). This limits the current study in that G studies should usually involve as many as possible potential sources of variation.

For the skill of essay writing, if more than one rater had graded *all* of the essays individually (in other words, a raters facet is crossed with the persons facet), part of the variation in the essay scores could have been attributed to the raters facet. Raters is often used as a random facet when a G study deals with subjective scoring (Marzano, 2002; Swartz et al., 1999; Gao & Brennan, 2001; Clauser, Swanson & Clyman, 1999).

Since *College BASE* was developed using IRT, the item difficulty levels tend to vary a lot because IRT favors items of different difficulty. However, in G theory, more diversity in difficulty levels means larger variance due to items and smaller generalizability coefficient. While a generalizability coefficient of nearly 0.6 is satisfactory to the researcher of this study, the heterogeneity of items analyzed is partly responsible for this not-high value.

On the other hand, unidimensionality of items and test is an important assumption in IRT, while G theory isn't picky in this aspect. G theory can deal with more dimensions. This is one of the advantages of G theory over IRT. Brennan (2001a) briefly compared G theory with IRT and concluded that G theory is primarily a sampling model whereas IRT is principally a scaling model. The fundamental difference between the two theories is the fixed/random feature (pp.175-176).

This G study is a balanced univariate one having equal number of items for each skill. An unbalanced or multivariate design can provide more information since multivariate G studies consider covariance as well as variance (Brennan, 2001a).

Another limitation of this study is reflected by the demographic descriptives. The number of females (880) was more than three times the number of males (273). The vast majority of the sample were White (1045 out of 1155). This reduces the generalizability of this study.

Suggestions for Future Studies

More Facets

In future G studies on people's writing ability, more facets should be included in the design, so that a more complete and detailed picture of the observed-score variance can be obtained. It is important to know what the sources of variation are in order to establish more dependable measurements of writing ability.

More Heterogeneous Population

The reliability appraisal of writing ability can be extended to a more heterogeneous population in future studies. While the target population of *College BASE* is collegians, the groups under-represented in this study (such as non-White groups) should be over-sampled in future in order to have more balanced sample sizes.

D Studies

This study didn't include any Decision Studies. Future D studies can be done on evaluating people's writing ability. In fact, D studies may be crucial for *College BASE* since it is a criterion-referenced test. Absolute decisions are usually made for criterion-referenced (domain-referenced) tests, where index of dependability instead of generalizability coefficient is calculated (Clauser, Swanson & Glyman, 1999).

One of the reasons the researcher of this study conducted a G study instead of a D study is that the researcher is more interested in decomposing variance than in the measurement precision of *College BASE*. Another reason is related to the limits of this study. Since too few facets were included in this study, decisions made from this study may not be well-grounded. Gao and Brennan (2001) pointed out that "predictions made about measurement precision based on G study may not match results from actual and distinct D studies". If the variance components from the current study were to be used to form D studies, the decisions would be too reckless.

G Studies on Other Clusters of College BASE

Future G studies can be done on the other eight clusters or on the subject-level of *College BASE*. The additional psychometric information will add to understanding of the test's reliability as well as validity.

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Table 1

Means and Standard Deviations of Writing Skills for Different Gender Groups

	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Male (n=273)	5.66 (1.517)	5.28 (1.881)	3.02 (0.578)
Female (n=880)	5.53 (1.533)	5.48 (1.710)	2.99 (0.519)
Combined (N=1155)	5.56 (1.529)	5.44 (1.753)	2.99 (0.536)

Note. Two people did not report gender. The numbers in the line of each row are means. The numbers in parentheses are standard deviations.

Table 2

Correlations among Writing Skills for Male Group

Males (n=273)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.396*	--	
Skill 106	.234*	.299*	--

Note. * p<.05.

Table 3

Correlations among Writing Skills for Female Group

Females (n=880)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.394*	--	
Skill 106	.246*	.259*	--

Note. * p<.05.

Table 4

Correlations among Writing Skills for the Combined Group

Combined (N=1155)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.392*	--	
Skill 106	.245*	.271*	--

Note. * p<.05.

Table 5

Means and Standard Deviations of Writing Skills for Different Ethnic Groups

	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay)
Asian/Pacific Islander (n=13)	5.23 (1.641)	6.46 [a] (1.898)	2.92 (0.494)
Black (n=62)	4.73 [a] (1.611)	4.19 [abc] (1.687)	2.63[a] (0.607)
White (n=1045)	5.62 [a] (1.508)	5.49 [b] (1.727)	3.02[a] (0.520)
Hispanic (n=17)	5.35 (1.498)	5.76 [c] (1.921)	2.71 (0.588)
American Indians/Alaskans (n=3)	5.33 (2.887)	3.33 (1.155)	2.67 (0.577)

Note. Fifteen people did not report gender or the data were missing. The numbers in the first line of each row are means. The numbers in parentheses are standard deviations.

[a] Means in the same column sharing the same letter superscript differ at *p*<.05 in the Post Hoc tests.

Table 6

Correlations among Writing Skills for Asian/Pacific Islander Group

Asian/Pacific Islander (n=13)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.471	--	
Skill 106	-.594*	.041	--

Note. * $p<.05$.

Table 7

Correlations among Writing Skills for Black Group

Black (n=62)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.496*	--	
Skill 106	.431*	.407*	--

Note. * p<.05.

Table 8

Correlations among Writing Skills for White Group

White (n=1045)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.378*	--	
Skill 106	.216*	.243*	--

Note. * p<.05.

Table 9

Correlations among Writing Skills for Hispanic Group

Hispanic (n=17)	Skill 104 (Writing as a Process)	Skill 105 (Writing Conventions)	Skill 106 (Essay Writing)
Skill 104	--		
Skill 105	.313	--	
Skill 106	.338	.156	--

Table 10

Distribution of Essay Writing Scores

Score	Frequency	Percentage
0	0	0
1	1	0.1
2	160	13.9
3	844	73.1
4	144	12.5
5	6	0.5
6	0	0

Table 11

Three Facet $p \times (i : t)$ *Design Treating All Facets as Random*

Source of Variation	df	Mean Squares	Estimated Variance Component	Percentage of Total Variance
Persons (p)	1154	0.46962	0.0164253	7.6
Skills (t)	1	1.09113	0.0[a]	0
Items: Skills (i:t)	14	11.41155	0.0097177	4.5
pt	1154	0.20681	0.0024022	1.1
pi:t, e	16156	0.18759	0.1875921	86.8

Note. [a]Negative estimate of variance was set to zero. Actual estimated value was -0.0011190.

Table 12

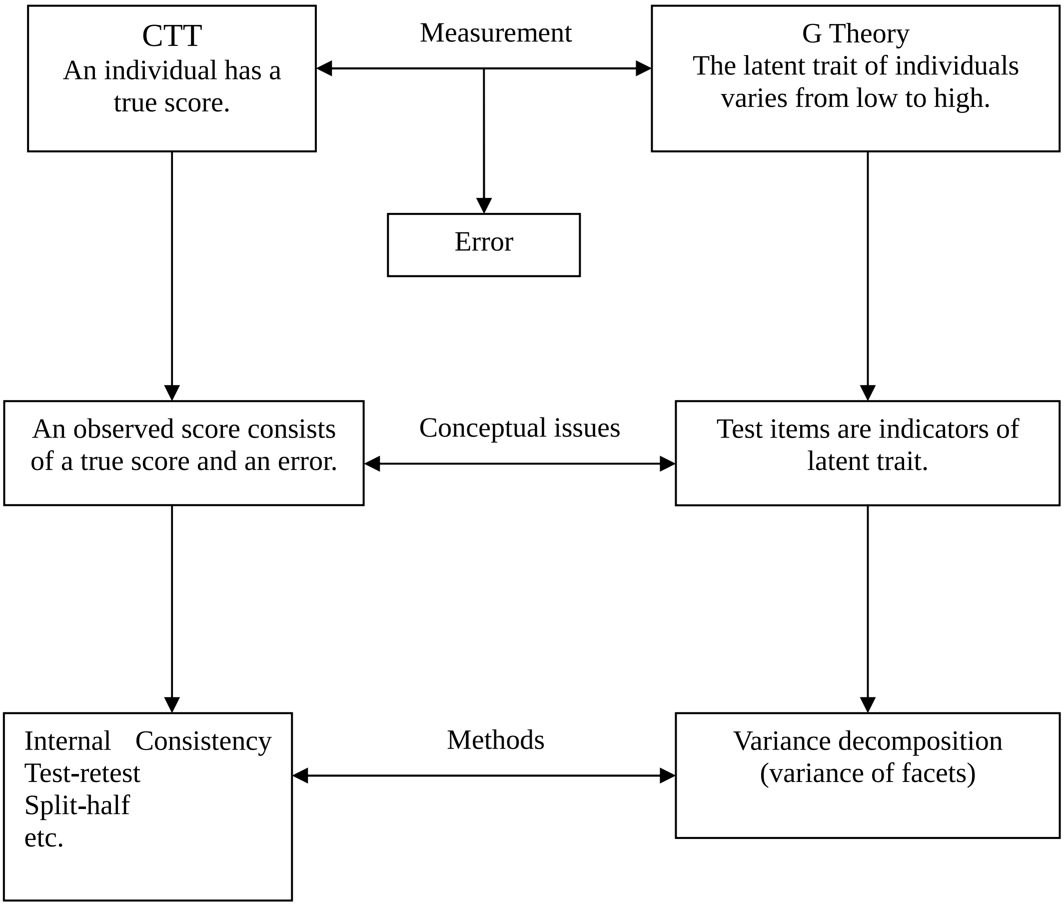
Analysis of the $p \times (i : t)$ *Design with t Fixed*

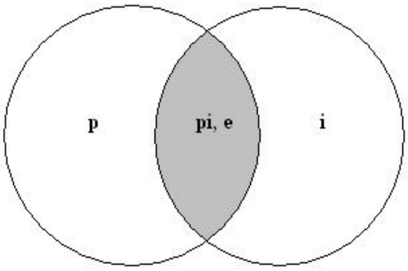
Source of Variation	Estimated Variance Component	Percentage of Total Variance
Persons (p)	0.0176265	8.2
Items: Skills (i:t)	0.0097177	4.5
pi:t, e	0.1875921	87.3

Figure Captions

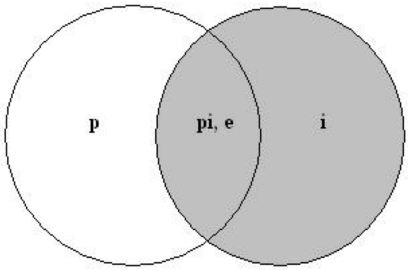
Figure 1. Graphical depiction of classical test theory and Generalizability theory.

Figure 2. Relative and Absolute Error for a Random $p \times i$ Design.


CTT
An individual has a true score.
Measurement
G Theory
The latent trait of individuals varies from low to high.
Error
An observed score consists of a true score and an error.
Conceptual issues
Test items are indicators of latent trait.
Internal Consistency
Test-retest
Split-half
etc.
Methods
Variance decomposition
(variance of facets)



Relative Error



Absolute Error

APPENDIX A

GENOVA Control Cards for $p \times (i : t)$ Design Treating All Facets as Random

```
STUDY          attempt=1 reason=1 promcode=6 q1-q16
COMMENT
COMMENT          # RECORDS = 1155
COMMENT          # VALUES PER RECORD = 16
COMMENT
OPTIONS        RECORDS ALL     CORRELATION
EFFECT         * P 1155 0
EFFECT         + T 2 0
EFFECT         + I:T 8 0
FORMAT           (16F2.0)
PROCESS
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FINISH

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0 1 0 0 0 0 1 0 1 0 0 0 1 0 0 0
1 1 0 1 0 1 1 1 1 1 1 1 1 0 0 1
1 0 0 1 0 1 1 1 0 1 1 1 1 1 1 1
1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 1
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FINISH

VITA

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