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The Measurement of Individual Differences in Preference for Numerical Information

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Abstract

This paper develops a measure of preference for numerical information and assesses the relationship of this construct to several other constructs. While past research has focused on constructs relating to numerical ability on the one hand and attitudes toward domains such as statistics and mathematics on the other, the construct of attitude toward numerical information has not been isolated and studied. The premise here is that it is important to understand the role played by attitude or proclivity toward numerically presented information since such attitudes could have important causal influences on several outcomes of interest such as statistical knowledge and numerical ability. The measure of preference for numerical information is tested for internal consistency, unidimensionality, and validity across several studies. Several interesting relationships of preference for numerical information with constructs involving numerical content such as statistics and mathematics as well as constructs relating to precise information such as tolerance for ambiguity are examined.

The Measurement of Individual Differences in Preference for Numerical Information

Several authors have documented the importance of numerical information in day-to-day life (cf., Paolos, 1988). While past research has focused on identifying constructs such as numerical ability, enjoyment of mathematics, and attitude toward statistics, there is a lack of a measure that taps individual differences in *preference for* or *attitude toward* numerical information. This study develops and validates a scale that aims to measure `preference for numerical information', a construct that taps proclivity toward using numerical information and engaging in thinking involving numerical information. It will be argued that it is important to understand the role of attitude toward numerical information as a separate and distinct domain. Further, the relationship between this construct and several other constructs is investigated here.

Review of Relevant Literature

While several measures of numerical and mathematical ability in the educational context are available from past research, there is a lack of measures of *attitude* toward numerical information. Past research of relevance includes measures of attitude toward statistics and mathematics which involve numerical content as well as aspects unique to statistics and mathematics. Hence, the focus is not on on numerical information per se. Some researchers have examined the notion of 'numeracy', a term that has been used as a parallel to literacy and has been argued to include aspects of both ability and attitude for numerical information in day to day life (Evans, 1989). While the context of numeracy is broader than the domain of education, it has been measured on the basis of problem solving skills that may be encountered in everyday situations (i.e., aspects of ability) rather than attitude toward numerically expressed information.

In the realm of attitude, several measures which may partially overlap with attitude toward numerical information are available in the literature. However, these measures assess domains which are not restricted purely to numerical information. Wise (1985) developed a scale of Attitude Toward Statistics to measure change in attitude among students of introductory statistics. The 29 item scale has two sub-scales; Attitude Toward Course and Attitude Toward the Field of statistics. The focus is on statistics rather than on numerical information. Aiken (1974) developed two scales of attitude toward mathematics referred to as enjoyment of mathematics and value of mathematics. The enjoyment of mathematics scale is argued to include a liking for mathematics as well as a liking for "mathematic terms, symbols, and routine computations" (Aiken, 1974, p. 67). The value of mathematics scale relates to the recognition of the importance of mathematics to individuals and to society. Again, in terms of content, attitude toward numerical information is not in primary focus here.

Researchers have used the term 'numeracy' as a parallel to the term literacy and pointed out the wide range of implications of innumeracy to individuals and to society (cf., Evans, 1989). The word `numerate' has been used to include the ability to meet the demands of day to day life in terms of mathematical needs as well as an understanding and an appreciation of quantitative information (Cockcroft, 1982). Researchers argue that the notion of numeracy is broader than just skills relating to computation and includes *both* ability and attitude, that the context of relevance is every day life and its practical demands in terms of coping with numerical information, and the emphasis is on appreciation as well as usage (Evans, 1989). Hence, the construct is argued to capture attitude and ability toward numerical information as well as mathematics in day to day life. Several researchers have reported on the level of numeracy among adults and children (Webb, 1984; Sheperd, 1984) using a survey that has items regarding "practical math" (ACACE, 1982; for e.g., "if five X'mas cards cost 65p, how much is each card costing you ?"). The survey poses questions involving the application of mathematical skills to everyday problems. While the confidence of respondents was observed and recorded in administering this survey (cf., Evans, 1989), it focuses primarily on ability to perform practical math problems rather than attitude toward numerical information.

It should be noted that, in addition to a focus on ability rather than attitude, a measure of problem solving skills with correct answers based on computations neglects the usage of numerical information in settings involving the processing of information without precise computations (i.e., mathematical skills). In situations such as a consumer having to make a decision based on numerical information about a product or an individual having to interpret statistical information about the likelihood of contracting a disease, no precise computations are involved. Yet, the neglect of numerical information may lead to a poor decision. In such situations, appropriate usage of numerical information may be influenced, not by ability to compute, but by a proclivity toward numerically expressed information and a prior knowledge that allows for the interpretation of such information. This aspect of proclivity toward numerical information may also be captured by the isolation and study of attitude toward numerical information rather than by focusing on problem solving involving computational skills.

The measurement of individual differences in attitude or proclivity toward numerical information has several implications in understanding the relationship between this construct and other constructs. The isolation of numerical information as the content domain is important in understanding the causal determinants of outcomes such as statistical or mathematical ability. In addition to other aspects that these domains tap, they are also characterized by the involvement of numerical information. As an example of potential insights to be gained by isolating and studying attitude toward numerical information, several researchers have pointed to problems that people have in of applying statistical principles to day to day problems (cf., Nisbett, Krantz, Jepson, & Kunda, 1983). Issues of interest here include the extent to involvement of numerical information underlies such phenomena. In other words, to what extent can a basic attitude toward numerical information influence attitudes and performance in domains involving numerical information. Further, the isolation of this construct allows for an understanding of its relationship with several constructs. For example, numerically presented information is relatively precise in its conveyance of meaning. Several constructs of importance in psychology relating to precise information such as tolerance for ambiguity may, hence, be related to attitude toward numerical information. Therefore, a comprehensive understanding of factors influencing outcomes such as numeracy and quantitative ability may be pursued.

In summary, the isolation and study of attitude toward numerical information is required since such a focus would allow for an understanding of the determinants of outcomes of importance such as low levels of numeracy and poor quantitative ability. Further, several situations involving the use of numerical information may not require mathematical skills but a tendency to use numerical information in decision making. Attitude rather than ability may be more useful in explaining the degree of usage of numerical information in such situations. This paper aims to develop and validate a measure of `preference for numerical information' (referred to as 'PNI'). Further, the relationship between PNI and other constructs are examined.

Development of a Measure of Preference for Numerical Information

Preference for numerical information is defined as *a preference or proclivity toward using numerically presented information and engaging in thinking involving numerical information.* Several aspects of this definition need to be noted. First, the focus is on preference or proclivity rather than ability. Hence, the aim here is to assess attitude toward numerically presented information. Second, the focus here is purely on numerically presented information rather than on domains such as statistics or mathematics. Hence, the aim is to isolate attitude toward numerical information from domains which involve the use of such information. Third, the context is not restricted to educational settings but is a general one that may apply more widely. Hence, this scale is somewhat similar to scales such as the 'Need for Cognition' scale (Cacioppo and Petty, 1982) that have a general rather than specific context and can be used in a variety of settings.

Item Generation

Items were generated for the PNI scale in line with an operationalization of the definition of the construct. As mentioned earlier, three aspects of importance in the definition relate to the focus on numerical information, the focus on preference or proclivity, and a general rather than specific context. The domain of the construct (i.e., numerical information) was operationalized by using terms such as "numbers," "numerical information," and "quantitative information". Hence, the substantive domain was operationalized by using parallel terms that represent numerical information. Proclivity or preference for numerical information was operationalized using a diverse set of elements or aspects such as the extent to which people enjoyed using numerical information (e.g., "I enjoy work that requires the use of numbers"), liking for numerical information (e.g., "I don't like to think about issues involving numbers"), and perceived need for numerical information (e.g., "I think more information should be available in numerical form"). Other aspects included usefulness (e.g., "Numerical information is very useful in everyday life"), importance (e.g., "I think it is important to learn and use numerical information to make well informed decisions"), perceived relevance (e.g., "I don't find numerical information to be relevant for most situations"), satisfaction (e.g., "I find it satisfying to solve day to day problems involving numbers"), and attention/interest (e.g., "I prefer not to pay attention to information involving numbers"). The use of information in a general rather than a specific context was captured by wording items to be general ("I prefer not to pay attention to information involving numbers") rather than specific to any context.

A pool of items were generated in line with the operationalization described above and were in the form of statements that could be agreed or disagreed with to varying degrees. A total of twenty items were chosen from this pool. These items were worded such that an equal number of items were positively or negatively worded with respect to preference for numerical information. The response format was a 7-point scale numbered from 1 to 7. The scale was labeled at the extremes as Strongly agree-Strongly disagree since responses involved degrees of agreement or disagreement with statements.

Several studies were conducted to assess the internal consistency and dimensionality of versions of the PNI scale with the final aim of developing a reliable, unidimensional measure. The premise here, based on the definition of the construct, was that preference for numerical information was a construct of a single dimension on which individuals differed. Three studies assessed the 20 item PNI scale with a view to investigating the performance of items of the scale across studies. Study 4 assessed the known-groups validity of the PNI scale (Thorndike, 1982) by comparing responses to the PNI scale of students enrolled in relatively 'quantitative' courses (i.e., courses offered at the engineering department) and students enrolled in relatively less 'quantitative courses (i.e., courses offered by the business administration and advertising departments). Based on these studies, three items were replaced with new items to form a modified scale that was assessed in Study 5. Study 6 and Study 7 were performed to assess the nomological validity of the PNI scale and to understand its relationship with several constructs.

Study 1

93 students enrolled in undergraduate courses at a midwestern university offered by either the business administration or the advertising departments completed the 20 item PNI scale. The data was analyzed by using reliability and factor analysis procedures. Items were scored such that a higher rating indicated greater preference for numerical information. Coefficient alpha for the 20 item scale was 0.89. The average inter-item correlation was 0.30 which was within the range of 0.2 to 0.4 suggested by Briggs and Cheeks (1986). Items were assessed by computing item-to-total correlations. One item had a negative item-to-total correlation (Item 12; see Table 1 for item-to total correlations, item means, and item standard deviations).

Insert Table 1 about here

Factor analysis was performed on the 20 item scale to assess its dimensionality. A common factor analysis led to the extraction of four factors accounting for 36.6%, 5.9%, 5.5%, and 3.3% of the variance with eigen values of 7.33, 1.18, 1.10, and 0.66, respectively. The existence of a dominant factor is clearly suggested here on the basis of a scree test. Eighteen items had their highest loading on the first factor (see Table 2 for items and loadings on the first factor). One item had a negative loading on the first factor (Item 12 which also performed poorly in terms of item-to-total correlations). Another item had an approximately equal loading on the first and second factors (Item 18). Based on this study, it appeared that most of the items of the scale were combining to form a reliable scale and tapping a general factor.

Insert Table 2 about here

Study 2

159 students enrolled in undergraduate courses offered by the department of business administration at a midwestern university completed the 20 item PNI scale. A coefficient alpha of 0.91 was obtained for the 20 item scale. The average inter-item correlation was 0.34 which was within the range suggested by Briggs and Cheeks (1986). One item had a correlation with the total of less than 0.20 (Item 12). Item-to-totals for other items ranged from 0.36 to 0.71 and are presented in Table 1 along with item means and standard deviations.

A common factor analysis led to the extraction of two factors with eigen values greater than one. The first factor accounted for 39.3 percent of the variance (Eigen value = 7.86) while the second factor accounted for 7.1 percent of the variance (Eigen value = 1.41), with a scree test suggesting the existence of a dominant factor. Nineteen items had highest loadings on the first factor (ranging from 0.38 to 0.82; see Table 2) while one item had a higher loading on a secondary factor (Item 12 which also had a low item-to-total correlation).

Study 3

90 students enrolled in undergraduate courses offered by the business administration department at a midwestern university completed the 20 item PNI scale. A coefficient alpha of 0.90 was obtained for the 20 item scale. The average inter-item correlation was 0.30. Two items had item-to-totals below 0.30 (Items 2 & 12; see Table 1). A common factor analysis led to the extraction of four factors with two of these factors having eigen values greater than 1. The first factor accounted for 33.8 percent of the variance (Eigen value = 6.76) while the second factor accounted for 8 percent of the variance (Eigen value = 1.60). The two items with low item-to-total correlations also had higher loadings with secondary factors (Items 2 & 12). The other 18 items had loadings ranging from 0.33 to 0.83 (see Table 2).

With most of the items of the PNI scale combining to form a reliable, unidimensional scale, evidence of its known-groups validity in terms of tapping the domain of numerical information was assessed in Study 4. Differences between students enrolled in courses offered by departments with relatively high quantitative content versus relatively low quantitative content were assessed in Study 4 on the premise that enrollment in such courses reflect inclination toward quantitative content among students.

Study 4

108 students who were enrolled in undergraduate courses offered by the engineering department at a midwestern university completed the PNI scale. This was with a view to assess differences between students enrolled in engineering courses (assumed to be high in preference for numerical information) with students enrolled in courses offered by the business administration and advertising departments (assumed to be relatively lower in preference for numerical

information). The mean score on the PNI scale was computed for each subject. A mean of 5.11 was obtained for this study which was significantly higher than the means in Study 1 (Mean = 4.66; t (199) = 3.75; $p < .001$), Study 2 (Mean =4.82; t (265) = 2.71; $p < .001$) and Study 3 (Mean = 4.78; t (195) = 2.82; $p < .001$)[1]. Further, most of the items on the scale had a higher mean for this study when compared to Study 1, Study 2, and Study 3 (see Table 3). The standard deviations for the scale in this study were also consistently lower than the standard deviations in other studies (Mean standard deviation = 0.72 versus 0.97, 0.94, and 0.92 in Study 1, Study 2, and Study 3, respectively). Therefore, higher scores and lower standard deviations on the PNI scale for students enrolled in engineering courses (assumed to be students with relatively high preference for numerical information) than for students enrolled in business or advertising courses (assumed to be students having relatively lower preference for numerical information). The results of this study provide some evidence for the validity of the PNI scale.

Insert Table 3 about here

Discussion of Results

Based on these studies, three items performed poorly in Study 1 and/or Study 2 and/or Study 3 (i.e, Items 2, 12, and 18). 17 items had performed well across several studies in terms of reliability and unidimensionality. An examination of means, standard deviations, and correlations to total of items suggests that comparable values were obtained across the three studies. The factor structure appears similar across the three studies in terms of the eigen values of extracted factors (Eigen values of the first factor were 7.33, 7.86, and 6.76 and eigen values of the second factor were 1.18, 1.41, and 1.60, respectively). The loadings of items on the first factor were also comparable with a moderate level of variation across studies.

The results of these four studies provided a basis to modify the existing scale. Three more items were generated and added to the 17 items to form a modified scale. These three items were generated to convey a similar meaning as each of the deleted items with modified wording to address some problems with each item.[2] This modified scale was assessed in another study in terms of internal consistency and factor structure.

Study 5

180 students enrolled in undergraduate courses offered by either the business administration or the advertising departments at a midwestern university completed the modified 20 item scale of preference for numerical information. Coefficient alpha for the 20 item scale was 0.94 with item-to-total correlations ranging from 0.46 to 0.82 (see Table 3 for items, means, standard deviations, and item-to-total correlations). The average inter-item correlation was 0.43 which is slightly above the range suggested by Briggs and Cheeks (1986). A common factor analysis led to the extraction of two factors with eigen values greater than one. A scree test suggested a dominant first factor (Eigen value = 9.01; %. of variance = 45.1%) with the other factor accounting for 6.9% (Eigen value = 1.38). All the items had their highest loadings on this dominant factor with loadings ranging from 0.50 to 0.84 (see Table 4). The eigen value of the first factor as well as the average size of the loadings on the first factor were higher for this study using the modified scale than for the first three studies using the original scale (i.e., 9.01 for Study 5 versus 7.33, 7.86, and 6.76 for Study 1, Study 2, and Study 3, respectively). Based on these studies, it appeared that the PNI scale was internally consistent and unidimensional, with some evidence of its validity. Several additional studies assessed the validity of the PNI scale.

Insert Table 4 about here

The PNI scale was evaluated by relating it to several constructs in an effort to assess its validity and to study its relationship to other variables. In Study 6, the relationship between PNI and social desirability, Need for Cognition, ACT scores, reported grades in quantitative courses and gender were assessed. In Study 7, the relationship between PNI and several constructs relating to attitude toward domains such as statistics were assessed as a means of evaluating the validity of the PNI scale. A positive relationship between PNI and attitude toward domains involving numerical content such attitude toward statistics was expected. Additionally, the relationship between PNI and constructs relating to preference for precise information were assessed to understand the nature of these relationships, on the premise numerical information represented a relatively precise means of conveying information. Finally, the relationship between PNI and ACT scores, reported grades in quantitative courses, and gender were assessed.

Study 6

The relationship between the PNI scale and the social desirability scale (Crowne and Marlowe, 1964) was assessed to examine whether responses to items indicating a higher (or lower) preference for numerical information may be partially explained by a motive to appear socially desirable. A possible explanation for such a reaction may be based on a perception that it is more socially desirable to indicate greater preference for numerical information. (This may particularly be likely given the composition of the sample which consisted of students, who, having taken quantitative courses, may indicate a greater preference for numerical information as a means of appearing socially desirable).

Need for Cognition (Cacioppo and Petty, 1982) is the "tendency of an individual to engage in and enjoy thinking." Since the PNI scale is argued to tap into individuals' preference for engaging in thinking involving numerical information as captured by aspects such as enjoyment and liking, a positive relationship would be expected between PNI and Need for Cognition. In other words, people who have a tendency to enjoy thinking may, in general, be more likely to have a proclivity toward thinking based on numerical information than people who do not enjoy thinking. Given the argument made earlier that the PNI scale taps preference for thinking based on numerical information, a positive correlation with the Need for Cognition scale would provide some evidence for this claim.

The relationship between the PNI scale and performance in statistics and quantitative courses were also assessed using several scales. One scale asked respondents for their grade in the most recent statistics course taken by them (with responses from A to E). Two scales asked subjects to indicate their grades in statistics courses and in quantitative courses taken in the past (using 6 point scales labeled ALL As through Almost all Cs). Self-reports of ACT scores and gender were collected.

Method

61 subjects completed the modified PNI scale and several other scales including a 33 item social desirability scale (Crowne and Marlowe, 1964), a shortened version of the Need for Cognition scale comprising of 18 items (Cacioppo, Petty, & Kao, 1984), and items described above relating to grades. Items on the PNI scale, Need for Cognition scale, and social desirability scale were scored such that higher ratings indicated higher preference for numerical information, higher Need for Cognition, and higher social desirability, respectively.

Results

The data was analyzed by computing the score on each scale for each respondent (i.e., the mean of the ratings on all the items of a scale).[3] PNI had a nonsignificant correlation with the 33 item social desirability scale ($r = 0.06$; $p > .30$).[4] Therefore, it appears that social desirability is not a significant factor in explaining responses to items on the PNI scale. PNI had a positive correlation with Need for Cognition ($r = 0.24$; $p < .05$). The significant correlation provides some evidence for the claim that the PNI scale taps proclivity toward thinking based on numerical information. The size of the correlation suggests that there is a significant but small relationship between PNI and Need for Cognition. Therefore, it appears that a tendency to enjoy thinking per se is not strongly related to a tendency to enjoy thinking based on information in a numerical form.

PNI was also related to each of the three scales relating to the most recent statistics course ($\underline{r} = 0.42$; $p < .01$), grades in statistic courses in the past ($\underline{r} = 0.40$; $p < .01$) and grades in quantitative courses ($\underline{r} = 0.53$; $p < .001$) with the scales being scored such that higher scores indicated better grades. ACT scores had a non-significant negative correlation with PNI . An examination of 'high' versus 'low' PNI scores (with a split made on the mean PNI score) was undertaken to investigate possible differences in ACT scores. The results suggested a directional but non-significant effect such that students with higher PNI scores tended to report higher ACT scores (Mean ACT scores of 28.2 versus 27.4 for the high PNI group (n=21) versus the low PNI group (n=29), respectively). Comparison of differences in PNI score based on gender suggested that males scored higher than females (Mean PNI scores of 4.75 versus 4.59 for males (n=20) versus females (n=40), respectively) but the difference was not significant.

Study 7

The relationship between PNI and several other constructs were assessed in another study. One set of constructs related to attitudes toward domains which involved the use of numerical information such as statistics and mathematics in order to assess the nomological validity of the PNI scale. The relationship between PNI and the Achievement Anxiety Test (Alpert & Haber, 1960) was examined in light of past research which has related this construct to constructs relating to academic achievement such as quantitative ability and attitude toward mathematics (Aiken, 1974). This was with a view to assessing similarities and distinctions between PNI and scales measuring attitude toward statistics and mathematics in the way in which they relate to other constructs. Another set of constructs that were examined related to preference for precise information since precision is argued to be a property of numerical information. The relationship between PNI and ACT scores, reported grades in quantitative courses, and gender were also assessed.

Relationship of PNI with Attitudes toward Statistics and Mathematics

As discussed earlier, Wise (1985) developed a 29 item scale that measures attitudes toward statistics to measure change in attitude among students of introductory statistics and consisting of two sub-scales: attitudes of students toward the course and attitudes of students toward the field of statistics. The relationship between this scale and the PNI scale was assessed here. Given the numerical content in statistics, a positive correlation between preference for numerical information and attitude toward statistics would provide evidence of the validity of the PNI scale. Aiken (1974) developed two scales of attitude toward mathematics with the enjoyment of mathematics scale argued to include a liking for mathematics as well as a liking for "mathematic terms, symbols, and routine computations" (Aiken, 1974) and the value of mathematics scale relating to the recognition of the importance of mathematics to individuals and to society. Given the numerical content that is involved in mathematics, a positive correlation was expected between these two scales and the PNI scale. The enjoyment scale would be related to the PNI scale based on the numerical content that overlaps these two constructs. To the extent that liking for numerical information is required for enjoyment of mathematics, a positive correlation would be expected between the two scales. The value of mathematics scale would be positively related to the PNI scale since they overlap in terms of numerical content in mathematics as well as in terms of the value or importance of mathematics and numerical information, respectively.

Relationship of PNI with Achievement Anxiety Test and Self-reports of Grades

The Achievement Anxiety Test (Alpert and Haber, 1960) consists of two sub-scales that tap the extent to which anxiety facilitates (referred AAT-F) and debilitates (referred to as AAT-D) performance in academic achievement situations. Watson (1988) studied the relationship between the Achievement Anxiety Test and constructs that relate to academic achievement including enjoyment of mathematics and value of mathematics (Aiken, 1974). Watson (1988) found a significant negative correlation between AAT-D and enjoyment of mathematics and a significant positive correlation between AAT-F and enjoyment of mathematics. A similar pattern of relationships were also obtained with a quantitative ability test. However, no significant correlations were found between the AAT scales and the value of mathematics scale. The relationship between PNI, attitude toward statistics and mathematics, and the anxiety test was assessed to further understand the nature of the relationship between PNI and constructs that have been related to attitude and ability in mathematics. Further, as in Study 6, self-reports of grades in quantitative/statistics courses were collected to assess the relationship between self-reports of academic achievement and the constructs discussed above.

Relationship between PNI and Constructs involving Precise Information

Researchers have pointed out that numerical information is characterized by the conveyance of relatively precise information (which allows for precise computations) when compared to other forms of information such as verbal labels (Viswanathan and Childers, 1992). Assigning numbers to events or objects provides a relatively exact rather than ambiguous way of representing information. In comparison, other forms of information such as verbal information tends to be relatively imprecise (cf., Beyth-Marom, 1982). This property of numerical information suggests a potential relationship between PNI and constructs related to precise information. In line with the rationale suggested above, PNI was expected to correlate positively with 'Need for Precision', a scale that taps preference for fine-grained or precise (as opposed to coarse-grained or imprecise) thinking (cf., Viswanathan 1992). A similar relationship was expected with ambiguity tolerance (Norton 1975) which refers to the extent to which ambiguous information is perceived as being a source of psychological discomfort or threat. Norton (1975) points out that the term ambiguity is used to mean information that may be subject to multiple meanings, be relatively vague, have some uncertainty, etc., as is the case with imprecise information. To the extent that such information is perceived as a source of threat or discomfort, a low tolerance for ambiguity is indicated. Therefore, it is possible that individuals who prefer numerical information may have less tolerance for ambiguity due to overlap between the two constructs in terms of precision.

Another construct with a potential relationship to precision that was examined here is breadth of categorization. Bruner and Tajfel (1961) define breadth of category as "the range of stimuli that are placed in the same class or category and share a common label." Precision would be related to breadth of categorization because the use of broad rather than narrow categories suggest a preference for imprecise as opposed to precise categories. The relationship between PNI and breadth of categorization was examined, particularly in light of past findings that narrow categorizers had higher quantitative ability using a category width scale (Pettigrew 1958). Pettigrew (1958) developed the category width scale which provided the average value of some category (such as average rainfall) and required respondents to choose from sets of alternatives to indicate the largest and smallest instance of that category, with respondents being identified as broad or narrow categorizers on the basis of the breadth of the range that they chose around the average value. This scale was used in the present study to assess the relationship between PNI and category width. (Another task used to asses breadth of categorization requires subjects to sort objects into categories either with or without the specification of a dimension wherein variables such as the number of sorted categories and breadth of categories are used to understand categorizing behavior (cf., Block, Buss, Blocke, & Gjerde, 1981).)

Method

174 subjects completed several scales including the PNI scale[5], the 29 item Attitude Toward Statistics scale consisting of two subscales (Wise, 1985), two scales of attitude toward

mathematics (Aiken, 1974), the Achievement Anxiety test (Alpert & Haber, 1960; which consisted of two subscales, debilitating test anxiety (10 items) and facilitating test anxiety (9 items)), the 20 item category width scale (Pettigrew, 1958), the 20 item need for precision scale (Viswanathan, 1992), the category width scale (Pettigrew, 1958), and a shortened version of the tolerance for ambiguity scale (Norton 1975).[6] Subjects also completed the three scales described earlier relating to self reports of grades in quantitative/statistics courses and reported their ACT scores and gender.

Results

The items on the various scales were scored such that higher scores indicated a higher level of the trait indicated by the label of each scale (for eg., greater tolerance for ambiguity, etc.).[7] Correlations between PNI and several constructs were computed across respondents based on mean scores on each scale.

Relationship of PNI with Attitudes toward Statistics and Mathematics

Positive correlations were obtained between the PNI scale and the enjoyment of mathematics scale ($r = 0.67$; $p < .01$), the value of mathematics scale ($r = 0.56$; $p < .01$), and the total attitude toward mathematics scale ($r = 0.74$; $p < .01$). Positive correlations were also obtained between the PNI scale and the attitude to statistics course scale ($r = .57$; $p < 0.01$), the attitude to statistics field scale ($r = 0.51$; $p < .01$) and the total statistics scale ($r = 0.61$; $p < .01$). The results suggest that PNI has strong relationships with the various sub-scales relating to mathematics and statistics, thereby providing evidence of the nomological validity of the PNI scale (see Table 5). Given the numerical content that PNI was argued to tap and the numerical content involved in domains such as statistics and mathematics, these results provide evidence of the nomological validity of the PNI scale in measuring preference for numerical information. PNI has comparable or higher correlations with the sub-scales of attitude toward mathematics (statistics) such as enjoyment of mathematics and value of mathematics scales than the correlations between these sub-scales, possibly because PNI overlaps with both sub-scales in terms of numerical content while the sub-scales overlap in terms of mathematical (statistical) content (see Table 5).

Insert Table 5 about here

Relationship of PNI with Achievement Anxiety Test and Self-reports of Grades

The PNI scale had a weak positive correlation with AAT-F ($r = 0.15$) and AAT-D ($r = 0.05$). (Comparison of low versus high PNIs based on a mean split led to no significant differences on the components of AAT. Comparisons based on the highest and lowest quartiles led to a significant difference for AAT-F (3.12 versus 2.86 for low versus high PNIs; $t(65) = 1.94$; $p < .05$) but not for AAT-D). The AAT-F and AAT-D scales had significant correlations with the enjoyment of mathematics scale (see Table 6) in line with past research (Watson 1988). However, the AAT-D scale also had a significant negative correlation with the value of mathematics scale, a result which was not found by Watson (1988). Further, a similar pattern of correlations were obtained with the attitude toward statistics course scale and the attitude toward statistics field scale. However, the correlations between components of AAT and PNI, while having the same directionality as with the mathematics and statistics scales, was not significant. The context as well as the domain of the mathematics and statistics scales may be closer to academic situations whereas the PNI has a more general context and may, therefore, not be as strongly related to anxiety in academic achievement. Therefore, anxiety in academic situations may be related more strongly to attitude toward mathematics and statistics than to attitude toward numerical information.

The three self-reports of grades in quantitative/statistics courses had significant positive relationships with the enjoyment of mathematics scale, attitude toward statistics course scale, and the AAT-F scale and a significant negative correlation with the AAT-D scale (see Table 6). However, these self-reports did not have significant relationships with the PNI scale in contrast to the results of Study 6. Hence, academic performance in quantitative/statistics courses was more strongly related to the mathematics and statistics scales than to the PNI scale. These results are also consistent with the pattern of results obtained for AAT. The results point to a distinction between the PNI scale, which has a general context, and the mathematics and statistics scales which are more closely related to academic performance. Hence, two aspects of academic achievement (i.e., AAT and self-reports of grades) were found to have different relationships with PNI and constructs such as attitude toward statistics and attitude toward mathematics.

Insert Table 6 about here

Relationship between PNI and Constructs involving Precise Information

The relationship between PNI and constructs relating to precise information were examined and the results are presented in Table 7. A positive correlation was obtained between PNI and the scale assessing need for precision ($r = 0.41$; $p < .01$) suggesting that higher need for precision is related to higher preference for numerical information. A negative correlation was obtained between tolerance for ambiguity and PNI ($r = -0.24$; $p < .01$) suggesting that greater PNI may be suggestive of less tolerance for ambiguity (i.e, ambiguous information may be seen as a source of threat or discomfort by people with greater preference for numerical information).These results support the suggested relationship between PNI and a cognitive style that is characterized by need for precise information as well as a tendency to perceive a threat or discomfort with ambiguous information. However, a non-significant relationship was found between PNI and category width. An additional study provided evidence of the relationship between categorizing behavior and PNI using a sorting task.[8]

An examination of 'high' versus 'low' PNI scores (with a split made on the mean PNI score) was performed to investigate possible differences in ACT scores. The results suggested a directional but non-significant effect such that students with higher PNI scores tended to report higher ACT scores which were similar to the results Study 6 (Mean ACT scores of 26.99 versus 26.55 for the high PNI group (n=69) versus the low PNI group (n=58). Comparison of differences in PNI score based on gender suggested that males scored higher than females (Mean PNI scores of 4.93 versus 4.75 for males (n=65) versus females (n=93) but the difference was not significant (t (156) = 1.16; $p < .25$) similar to the results in Study 6.

Discussion

The importance of isolating and studying attitude toward numerical information rather than focusing on ability and attitude in domains that are purely restricted to numerical information such as mathematics and statistics was argued for several reasons. Such an approach would allow for a better understanding of the nature of the relationship of a basic attitude or preference for numerical information with constructs such as numeracy and mathematical ability. Further, several situations in everyday life require the use of numerical information without necessarily involving computations (such as the interpretation of statistical information in order to make decisions). Such usage of numerical information may be captured by measures of attitude toward numerically presented information rather than measures of ability to perform computations.

PNI was defined as a preference or proclivity toward using numerically presented information and engaging in thinking involving numerical information. A pool of items were generated in line with this definition. Twenty items were chosen from this larger pool and assessed across three studies. High coefficient alphas were obtained across the three studies. Most of the items performed well across the three studies in terms of item-to-total correlations. Factor analyses suggested the existence of a dominant first factor and most of the items performed well across three studies in terms of their loadings on the dominant factor. Based on these three studies, it appeared that most of the items combined to form a reliable scale that was tapping a unidimensional construct. The items that performed poorly were replaced with new items and the modified scale was assessed in another study. All the items performed well in this study in terms of internal consistency and unidimensionality.

Several lines of evidence were provided for the validity of the PNI scale. Given the focus on numerical content, comparisons were made between students enrolled in courses offered by relatively a ‘quantitative’ department (i.e., engineering) and students enrolled in courses offered by relatively less quantitative departments to assess the known-groups validity of the PNI scale. The mean scores for 'quantitative' students were compared to means scores from the studies using 'less quantitative' students. 'Quantitative' students had a significantly higher score than 'less quantitative' students, therefore, suggesting that PNI was tapping preference for numerical information to the extent that such a preference is related to student enrollment in different courses. The PNI scale was related to constructs involving the use of numerical information such as attitude to mathematics and attitude to statistics, thereby providing evidence of the nomological validity of the PNI scale as a measure of preference for numerical information. PNI had a positive relationship with Need for Cognition, a relationship that was expected, given the intent of the PNI scale to capture a tendency to engage in thinking based on numerical information. Further, the PNI scale had a non-significant correlation with the social desirability scale. Hence, it appears that social desirability is not an important factor in determining responses to the PNI scale.

Several interesting conclusions can be drawn about the relationship between PNI and other constructs. PNI had strong relationships with attitude to mathematics and attitude to statistics. A tentative explanation here may be that attitudes toward numerical information may have a causal influence on attitude toward math and statistics. While this claim is purely speculative from a theoretical standpoint, the size of correlations between PNI and the various sub-scales of mathematics and statistics suggest future research efforts in this direction. PNI had a non-significant relationship with anxiety facilitation and anxiety debilitation. However, in line with past research,the two components of the achievement anxiety test had a significant correlation with the enjoyment of mathematics scale. In addition, significant relationship was found with the value of mathematics scale. The components of AAT were also significantly related to the sub-scales of attitude toward statistics. A similar pattern of results were obtained with self-reports of grades in quantitative/statistics courses, though the relationship of grades with PNI varied between Study 6 and Study 7. Therefore, an important distinction between PNI and other constructs that are more closely related to academic achievement was identified which is consistent with the general rather than educational context of the PNI scale.

Another set of constructs that were examined related to precise information. PNI had a negative relationship with tolerance for ambiguity and a positive relationship with need for precision. PNI had a positive relationship with the number of categories that individuals used to sort objects. It is possible that the precision of numerical information may be a mechanism by which constructs such as PNI and quantitative ability relate to constructs such as breadth of categorization and tolerance of ambiguity. It is also possible that, given the use of relatively imprecise (i.e, verbal) information in day to day life (Zimmer, 1984), a tendency to avoid precise information may partially underlie low levels of PNI and quantitative ability. Future efforts could focus on a further understanding of the nature of the relationships between these constructs.

In conclusion, a construct tapping attitudes toward numerical information was defined and a scale measuring this construct was developed and assessed for reliability and validity. Several interesting relationships between this construct and constructs relating to attitudes toward mathematics and statistics, and constructs relating to precise information were found. The construct of PNI appears to be captured by a reliable, valid scale and appears to have relationships with several constructs that provide promising avenues of future research.

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Footnotes

1 Means were computed based on the 17 items that performed well across the first three studies. Coefficient alpha for the PNI scale was 0.87 with two items having item-to-total correlations below 0.3 (Item 2 and Item 12). The average inter-item correlation was 0.25. A common factor analysis led to the extraction of five factors with two factors having eigen values greater than 1. These two factors accounted for 33.5% and 8.1% of the variance, respectively (with eigen values of 6.7 and 1.6 respectively) with a scree test suggesting the existence of a dominant factor. All the items had their highest loadings on this dominant first factor except Items 2, 9, and 12. Item 9 which performed well in other studies had a loading of 0.27 with the first factor in this study.

2 Item 2 was originally worded to refer to the ease of understanding "information that does not involve numbers", an item that may have been tapping preference for non-numerical information (see Table 2). Such a preference for non-numerical information may or not may correlate negatively with preference for numerical information since it does not necessarily follow that a preference for numerical information means a lack of preference for non-numerical information. Rather than retain an item that was premised on a negative correlation between PNI and preference for non-numerical information, the new Item 12 was worded in terms of difficulty of understanding quantitative information (see Table 4). Similarly, the original Item 12 was worded in terms of qualitative information while the new item was in terms of numerical information (see Tables 2 and 4). It should be noted that items 2 and 12 performed poorly across several studies. Item 18, which performed poorly in one study, was originally worded in terms of "learning and remembering" numerical information (see Table 2). It was simplified by wording using only "learning" (see Table 4).

3 The reliability of the 18 item Need For Cognition scale was 0.86. The reliability of the 33 item Social desirability scale was 0.60. (Deletion of 5 items from the scale with negative item-to-total correlations led to a reliability of 0.66.)

4 PNI also had a non-significant correlation with the more reliable 28 item social desirability scale (r = -0.01).

5 This study employed the original PNI scale since the data was collected in conjunction with data collection for Study 2. Therefore, data analysis was based on the 17 items that were chosen for the final, modified PNI scale.

6 Norton (1974) presents 61 items of ambiguity tolerance relating to several domains such as philosophy, public image, etc. Fourteen items were chosen from the pool such that the various domains (seven in all) were represented in approximate proportion to the total number of items in each domain presented by the author.

7 Coefficient alphas of the various scales were assessed and are indicated in parenthesis for each scale; the enjoyment of mathematics scale (0.92), the value of mathematics scale (0.77), the total math scale (0.90), the attitude to field of statistics scale (0.90), the attitude to statistics course scale (0.89), the total attitude toward statistics scale (0.91), the anxiety facilitation scale (0.57), the anxiety debilitation scale (0.77), the total anxiety scale (0.78), the category width scale (0.85), the tolerance for ambiguity scale (0.71), and the Need for Precision scale (0.84).

8 To further investigate the relationship between PNI and categorizing behavior, a study using a sorting task was employed. The sorting task required subjects to sort a set of objects into groups on the basis of a particular specified attributes. Subjects completed four such sortings for different object-attribute combinations. Each sorting consisted of 12 objects such as 12 brands of soft drink that were sorted on the basis of sweetness). The instructions provided to subjects

followed past research (cf., Block et al., 1981) in that they were asked to sort the objects in any way they chose. 40 students at a midwestern university completed four sorting tasks and filled out the PNI scale. The number of groups that products were sorted into for each product category were treated as items in a multiple item scale. Coefficient alpha for the 4 item scale was 0.77. A significant positive correlation was obtained between PNI and sortings ($r = 0.46$; $p < .01$; $n=39$).

Table 1

Item Statistics for Study 1, Study 2, & Study 3

	Study 1			Study 2			Study 3		
Item	Mean	SD	ITT	Mean	SD	ITT	Mean	SD	ITT
1	4.34	2.04	0.77	4.96	1.74	0.71	4.72	1.82	0.75
2	3.73	1.62	0.36	3.77	1.48	0.36	3.68	1.65	0.27
3	4.40	1.60	0.75	4.59	1.69	0.70	4.34	1.74	0.77
4	5.27	1.43	0.58	5.38	1.29	0.67	5.38	1.19	0.54
5	5.33	1.30	0.48	5.22	1.34	0.61	5.21	1.40	0.44
6	3.99	1.43	0.63	4.06	1.40	0.67	4.30	1.28	0.65
7	5.00	1.41	0.79	5.21	1.41	0.67	5.04	1.33	0.60
8	4.73	1.42	0.44	4.79	1.36	0.39	4.90	1.37	0.38
9	4.35	1.43	0.48	4.13	1.47	0.67	4.22	1.40	0.54
10	4.55	1.66	0.73	4.90	1.57	0.74	4.67	1.52	0.74
11	5.08	1.33	0.48	5.04	1.41	0.37	4.95	1.34	0.48
12	3.43	1.38	-0.36	2.99	1.26	0.17	3.00	1.08	0.21
13	5.10	1.36	0.51	5.42	1.32	0.49	5.35	1.37	0.32
14	4.33	1.55	0.63	4.68	1.60	0.59	4.63	1.58	0.50
15	4.86	1.22	0.46	5.06	1.19	0.41	4.99	1.23	0.50
16	5.08	1.36	0.61	5.43	1.05	0.52	5.33	1.11	0.60
17	5.02	1.21	0.53	5.03	1.19	0.51	5.04	1.18	0.32
18	5.24	1.12	0.39	5.10	1.43	0.50	5.20	1.25	0.53
19	3.70	1.57	0.53	3.92	1.72	0.70	3.70	1.70	0.64
20	4.25	1.61	0.63	4.46	1.65	0.61	4.28	1.74	0.62

Note. SD = Standard deviation of item; ITT = Item to total correlation.

Table 2

Item Loadings on First Factor for Study 1, Study 2, & Study 3

		Study 1	Study 2	Study 3
1.	I enjoy work that requires the use of numbers.	0.80	0.79	0.80
2.	I find information easy to understand if it does not involve numbers.	0.37	0.42	0.28*
3.	I find it satisfying to solve day to day problems involving numbers.	0.78	0.75	0.83
4.	Numerical information is very useful in everyday life.	0.63	0.70	0.57
5.	I prefer not to pay attention to information involving numbers.	0.54	0.63	0.50
6.	I think more information should be available in numerical form.	0.63	0.75	0.67
7.	I dont like to think about issues involving numbers.	0.82	0.72	0.64
8.	Numbers are not necessary for most situations.	0.48	0.50	0.39
9 .	Thinking is enjoyable when it does not involve quantitative information.	0.45	0.69	0.55
10.	I like to make calculations using numerical information.	0.73	0.81	0.79
11.	Quantitative information is vital for accurate decisions.	0.58	0.38	0.55
12.	I enjoy thinking based on qualitative information.	-0.32	0.28*	0.22*
13.	Understanding numbers is as important in daily life as reading or writing.	0.55	0.53	0.35
14.	I easily lose interest in graphs, percentages, and other quantitative information.	0.68	0.63	0.53
15.	I don't find numerical information to be relevant for most situations.	0.52	0.43	0.54
16.	I think it is important to learn and use numerical information to make well informed decisions.	0.68	0.59	0.65
17.	Numbers are redundant for most situations.	0.57	0.55	0.33
18.	Learning and remembering numerical information about various issues is a waste of time.	0.42*	0.65	0.55
19.	I like to go over numbers in my mind.	0.58	0.69	0.72
20.	It helps me to think if I put down information as numbers.	0.67	0.70	0.66

Note. * = Equal or higher loadings on secondary factors

Table 3

Item Statistics for Study 4

Item	Mean	SD	ITT
1	5.49	1.17	0.66
2	3.97	1.43	0.23
3	4.99	1.24	0.57
4	5.60	1.07	0.43
5	5.58	0.97	0.47
6	4.32	1.19	0.46
7	5.54	0.94	0.61
8	4.89	1.22	0.49
9	4.39	1.11	0.32
10	5.32	0.99	0.64
11	5.37	1.17	0.48
12	3.11	1.12	-0.05
13	5.67	1.19	0.42
14	5.28	1.12	0.51
15	5.29	0.97	0.62
16	5.75	0.85	0.54
17	5.23	1.10	0.41
18	4.94	1.14	0.51
19	4.12	1.50	0.47
20	4.92	1.33	0.59

Note. SD = Standard deviation of item; ITT = Item to total correlation.

Table 4

Item Statistics and Loadings on First Factor for Study 5

		Mean	S.D.	ITT	Loading
1.	I enjoy work that requires the use of numbers.	4.82	1.84	0.76	0.79
2.	I think quantitative information is difficult to understand.*	4.93	1.59	0.64	0.68
3.	I find it satisfying to solve day to day problems involving numbers.	4.51	1.65	0.66	0.70
4.	Numerical information is very useful in everyday life.	5.20	1.44	0.68	0.70
5.	I prefer not to pay attention to information involving numbers.	5.36	1.39	0.70	0.71
6.	I think more information should be available in numerical form.	4.36	1.45	0.54	0.57
7.	I dont like to think about issues involving numbers.	5.10	1.55	0.82	0.84
8.	Numbers are not necessary for most situations.	4.70	1.58	0.46	0.50
9 .	Thinking is enjoyable when it does not involve quantitative information.	4.34	1.55	0.65	0.66
10.	I like to make calculations using numerical information.	4.84	1.57	0.73	0.76
11.	Quantitative information is vital for accurate decisions.	5.01	1.31	0.62	0.65
12.	I enjoy thinking about issues that do not involve numerical information.*	3.67	1.65	0.49	0.50
13.	Understanding numbers is as important in daily life as reading or writing.	5.27	1.48	0.57	0.60
14.	I easily lose interest in graphs, percentages, and other quantitative information.	4.77	1.63	0.65	0.68
15.	I don't find numerical information to be relevant for most situations.	5.03	1.27	0.71	0.75
16.	I think it is important to learn and use numerical information to make well informed decisions.	5.39	1.18	0.61	0.65
17.	Numbers are redundant for most situations.	5.10	1.17	0.58	0.62
18.	It is a waste of time to learn information containing a lot of numbers.*	5.11	1.39	0.55	0.57
19.	I like to go over numbers in my mind.	4.18	1.69	0.68	0.70
20.	It helps me to think if I put down information as numbers.	4.54	1.67	0.65	0.68

Note. * = New items that replaced items that performed poorly in the first three studies.

Table 5

Correlations between PNI and Attitudes toward Mathematics and Statistics

	PNI	MEN	MVL	MTH	ATF	ATC
MEN	0.67					
MVL	0.56	0.41				
MTH	0.74	0.93	0.73			
ATF	0.57	0.42	0.46	0.50		
ATC	0.51	0.65	0.41	0.50	0.49	
ATS	0.61	0.64	0.49	0.69	0.79	0.92

Note. All correlations were significant at the 0.01 level. MEN = Enjoyment of mathematics scale; MVL = Value of mathematics scale; MTH = Total attitude toward mathematics scale; ATF = Attitude toward statistics field scale; ATC = Attitude toward statistics course scale; ATS = Total attitude toward statistics scale

Table 6

Correlations between PNI and Achievement Anxiety and Self-reports of Grades

	PNI	MEN	MVL	MTH	ATF	ATC	ATS	AAT-F	AAT-D
AAT-F	0.15	0.24**	0.22**	0.27**	0.16*	0.29**	0.27**		
AAT-D	-0.05	-0.18*	-0.15	-0.19*	-0.10	-0.30**	-0.16*		
GRREC	0.06	0.26**	0.10	0.24**	0.06	0.40**	0.31**	0.37**	-0.31**
GRST	0.06	0.25**	0.13	0.24**	0.08	0.46**	0.35**	0.34**	-0.28**
GRQNT	0.09	0.27**	0.08	0.24**	-0.01	0.27**	0.18*	0.33**	-0.22**

Note. MEN = Enjoyment of mathematics scale; MVL = Value of mathematics scale; MTH = Total attitude toward mathematics scale; ATF = Attitude toward statistics field scale; ATC = Attitude toward statistics course scale; ATS = Total attitude toward statistics scale; AAT-F = Achievement anxiety test - Facilitation scale; AAT-D= Achievement anxiety test - Debilitation scale; GRREC= Grade in most recently taken statistics course; GRST = Average grade in statistics courses taken in the past; GRQNT= Average grade in quantitative courses taken in the past.

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