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Personal Need for Structure: Indiscriminate Classification Systems As Barriers to Processing Mathematical Complexity

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Abstract

This study applied previous research findings on stereotyping and individual differences in the need for simple structure to an investigation of math anxiety, finding that the same indiscriminately broad categorical thinking that underpins social stereotyping similarly affects math anxious students' processing of mathematical complexity. Study participants who scored high in the need for simple structure were significantly more likely to experience math anxiety. In addition, this investigation revealed that participants' implicit assumptions about the origins of math intelligence covaried with math anxiety and the need for simple structure. The potential benefits of introducing the conceptual underpinnings of math problems in a simple, straightforward fashion prior to increasing task difficulty were explored through the presentation of two progressively challenging counting tasks. While math anxious participants performed significantly worse than their non-anxious peers on the initial simpler task, as complexity increased, math anxious individuals' degree of success on the second, more challenging task paralleled that of their non-anxious peers. Taken together, these study findings inform our understanding of math anxious students' cognitive barriers to mathematical comprehension and fluency and suggest specific pedagogical strategies that might be employed to address these issues.

Keywords: simple structure, math anxiety, implicit theory, stereotype, education, gender

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The primary purpose of this study was to bridge previous research findings on social stereotyping with further exploration into math anxious students' maladaptive modes of integrating information. To date, the bulk of the stereotyping literature has concentrated on social realms, specifically observing the propensity to form broad, indiscriminate categories with respect to others. Far fewer researchers have focused on broad categorical thinking in nonsocial arenas. Neuberg and Newsom (1993) did, however, find a significant correlation between study participants' responses to complexity when categorizing social and nonsocial stimuli. More specifically, their data demonstrated that the same predisposition towards categorical thinking that underlies social stereotyping may similarly affect cognitive processing during nonsocial categorization tasks. A possible explanation for these findings comes from work carried out by Thompson, Naccarato, and Parker (1989). These investigators found individual differences in the need for simple structure, operationalized as the extent to which persons routinely seek out situations that are structured and predictable, while avoiding other situations that contain ambiguity and uncertainty. When inundated with information, individuals high in the need for simple structure seek to avoid excess stimuli by organizing what they perceive to be intractable complexities into simplistic categories that are more quickly and easily understood (Neuberg & Newsom, 1993). Importantly, this same application of a simplified, indiscriminate cognitive structure on mathematical concepts and procedures may explain why some persons face greater challenges than others when confronted with situations requiring effective mathematical concept integration and application.

Investigations have shown that when faced with mathematical complexity, math anxious students demonstrate decreases in computational accuracy that are far more pronounced than those of their non-math anxious peers (Kellogg, Hopko, & Ashcraft, 1999). Several studies have indicated that math anxiety interferes with cognitive processing via the reduction of working memory capacity (Ashcraft & Kirk, 2001). Those prone to experience math anxiety demonstrate insufficient inhibition in restricting "task-irrelevant distracters" from consuming cognitive resources (Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998). Studies like these have done much to increase our understanding of mathematics anxiety and its impact on student performance. However, while anxiety-induced temporary working memory deficits may explain the relation between math anxiety and achievement (Ashcraft & Kirk, 2001), this memory deficit model may not capture the cognitive coping mechanisms math anxious students tend to enlist while their available working memory is temporarily compromised.

Neuberg and Newsom (1993) identify two primary strategies for reducing cognitive load: Avoidance strategies and the imposing of a simplified structure on complex stimuli. Math anxious students have, in fact, been found to utilize avoidance strategies, as evidenced by the fact that they are far less likely than their non-anxious peers to select math-based elective classes (Ashcraft, 2002). Should math anxious individuals be confronted with compulsory math courses, it seems plausible to suggest that they might be prone to engage in generalized categorical thinking in an effort to impose a simplified structure on an otherwise anxiety-invoking subject matter. Further, Oberlin's 1982 study (as cited in Furner and Duffy, 2002) found that when students are told that there is only one correct path to a problem's solution, this information furthers the apprehensive thinking of already math anxious students. Math anxious students who adopt the belief that there exists a singular path toward a problem's solution may become rigid in their mathematical reasoning, which could, in turn, encourage them to seek a simple structure when processing mathematical content. In the present investigation, it was hypothesized that for math anxious students, the same predisposition towards oversimplified, categorical thinking that has been identified in the social psychological literature on stereotyping would underlie the formation of cognitive generalizations when processing mathematical complexity on both behavioral and questionnaire measures.

Research on implicit theories about the origins of human attributes has delineated two primary perspectives. Some individuals adopt what is termed an "entity" theory perspective, and regard individual differences in various abilities and characteristics as being relatively fixed. Others tend toward an "incremental" theory, and view differences as malleable and subject to change as the result of educational exposure and effort expenditure (Dweck, 2000). Importantly, one body of work (Levy, Stroessner, & Dweck, 1998) found a definitive link between the adoption of an entity theory perspective and the propensity toward stereotyping in social situations. Stereotyping is inherently less time consuming than are attempts to discern subtleties in nuanced information. Examining these entity vs. incremental theory differences further, entity theorists have been found to believe that effort expenditure is indicative of an innate cognitive weakness, while speed to solution is seen as suggestive of natural ability and giftedness (Dweck, 2007). This emphasis on speed could increase the desire to impose a simple structure, inasmuch as simple structures enable quick cognitive processing. Previous research focused specifically in the area of mathematics has found that beliefs about the origin of math intelligence are consequential in determining students' perceived levels of mathematical competence and subsequent effort expenditure (Ceci & Williams, 2007). The present investigation tested the hypothesis that participants' implicit assumptions about math intelligence would covary with generalized, simplified categorical thinking in mathematics.

Research centered on the consequences of adopting either a fixed or incremental theory of intelligence has contributed significantly to the study of how to help students realize their academic potential, and this work has also expanded our understanding of the basis of learning-centered anxiety (Dweck, 2007). For those who hold an entity theory perspective, "perfection with ease" serves as the ultimate indicator of intelligence; and as a result, entity theorists set unreasonably high expectations and are predisposed to experience heightened levels of anxiety (Dweck, 2007). Feelings of anxiety and inadequacy can interfere with efficiency in cognitive processing and often lead to maladaptive coping strategies (Rattan, Good, & Dweck, 2012). Consistent with the existing literature showing that fixed mindsets can instigate anxiety (see Dweck, 2007), and demonstrating that an incremental perspective can assuage anxiety (Burns & Isbell, 2007), it was hypothesized that math anxious students would be more likely than their less anxious peers to adopt an entity theory perspective on the origin of math intelligence.

This study served as a first step towards assessing the extent to which individual differences in the need for simple structure may offer an explanation for the computational and conceptual errors made when processing mathematical information. The investigation of whether, in fact, math anxious students demonstrate the tendency to seek simple structure in mathematics holds the potential to augment our understanding of why math anxious students may fail to perform at a level commensurate with their intellectual capacity. While the imposition of a far too simplistic information structure can lessen anxiety, ultimately this tactic may lead to the coupling of unrelated constructs and the indiscriminate application of inappropriate procedures. Predispositions towards categorical thinking may potentially impact students' knowledge acquisition and processing of information, particularly when the material being presented is perceived to be especially complex. The present study offered an empirical test of the relation between math anxiety and the propensity to organize mathematical concepts into an oversimplified structure. Data indicating that math anxiety and the tendency to oversimplify mathematical concepts covary could potentially reveal one mechanism whereby cognitive coping strategies hinder demonstrated math ability. This study also examined the extent to which the provision of tasks designed to expose students to slowly increasing, incremental levels of difficulty might promote the adoption of more accurate cognitive processing strategies.

This research was additionally motivated by previous findings showing that women are underrepresented in math-intensive disciplines. Women are more likely than men to hold the perspective that intelligence is fixed (Dweck, 2000), and they are also likely to be cognizant of the widespread, albeit erroneous, assumption that females are naturally less mathematically inclined than are their male counterparts (Meece, Wigfield, & Eccles, 1990). Entity theorists are generally less willing to expend effort in mathematical endeavors when they believe that a glass ceiling of limitations determines their cognitive capacity and performance (Blackwell, Trzesniewski, & Dweck, 2007). Young educated women cannot help but be aware of the discrepancy between the number of men and women who have gained prominence in mathematically-based fields. For female students adopting a fixed theory of intelligence, the belief that they must work far harder than their male peers and may never achieve the same level of mathematical ability might deter them from the study of pure math or math-related disciplines. Study participants in this investigation who experience math anxiety, are high in the need for simple structure and/or adopt an entity theory perspective on the origin of math intelligence were hypothesized to be found less likely to major or minor in math-intensive disciplines.

The primary hypothesis driving this investigation was that, when confronted with mathematical content, math anxious respondents would demonstrate the need to impose inappropriate and maladaptive broad categorical thinking. This hypothesis was driven in large part by the social cognition literature that focuses on the cognitive processes that underlie stereotyping in social realms. Further, those who adopted an entity theory perspective were predicted to be high on math anxiety and/or the need for simple structure. Taken together, the literature on anxiety, social stereotyping, and implicit theories of intelligence hold the potential to inform our understanding of the specific cognitive responses to complexity that may underlie barriers to effective mathematical processing and computation. This research also sought to explore the impact of presenting complex mathematical concepts via a series of incremental steps designed to address the cognitive and affective needs of math anxious students while at the same time promoting the development of valid mathematical reasoning abilities.

Method

Participants

The participant pool was comprised of 97 undergraduate students attending Wellesley College. Forty-one of these students were currently enrolled in psychology courses and received course credit for their study participation. The remaining 56 students were recruited via online postings to campus Google conferences. Targeted recruitment of students majoring in mathematics and other STEM disciplines was also carried out. Participants not drawn from the psychology research pool were compensated $10 each for their time.

Design Overview

After hearing a brief experimental overview and signing a written consent form acknowledging voluntary participation, participants were seated in front of computers and instructed to follow the directions as they appeared on the screen in front of them. Questions and tasks were presented in a randomized order, with the exception of a demographics questionnaire that was always presented last. Data were collected electronically via a web-hosted computer program designed specifically for this study. Confidentiality was maintained via the assignment of random subject numbers/survey numbers attached to each pre-loaded program. No names or other identifying information were gathered, beyond correspondence during recruitment and the signing of consent forms.

Incremental Steps Task

Math-anxious students struggle with single-digit operands more so than their less math anxious peers, and these anxiety effects are substantially aggravated and magnified when numerical complexity increases (Ashcraft & Faust, 1994). These findings highlight the impact of math anxious students' temporary working memory deficits on demonstrated speed and accuracy in numerical manipulations (Ashcraft & Faust, 1994). This study sought to observe whether math anxious students were similarly adversely affected when rote memorization was deemphasized, and the focus shifted towards building a conceptual understanding. To achieve this end, two triangles were presented in sequence. The initial, simpler triangle task presented eight smaller triangles embedded within a single larger triangle; while the second, more challenging triangle task presented 26 triangles again contained within the framework of a single larger triangle (see Appendix A and B). The second of these tasks was far more challenging than the first. For each of these two triangle problems, participants were asked to report the number of triangles they saw. They were told that they had unlimited time to answer these two geometrically-based, spatial questions and that they would be permitted to make multiple attempts, receiving instantaneous feedback as to whether their response was correct after each submission.

Categorical Thinking Task

While the vast majority of research on individual differences in the need for simple structure has been carried out within the socio-cognitive subfield of interpersonal stereotyping, Neuberg and Newsom (1993) did explore nonsocial categorical thinking with regard to over-stimulation in the physical environment. These researchers found that when study participants were presented with an array of pictures and were asked to form groupings comprised of as many or as few images as they saw fit, those scoring high in the need for simple structure created larger, less complex groupings. In addition, unlike their peers who scored low on this dimension, those who were high in the need for simple structure did not demonstrate a categorical plasticity, but instead placed items into a singular category and were unwilling to see them as simultaneously belonging to two or more categories.

Drawing from Neuberg and Newsom's (1993) research methodology, a measure of categorical thinking in mathematical expression classification was administered. This measure asked participants to group mathematical expressions based on their perceptions of the expressions' similarities to one another. Participants were presented with a 3 x 5 grid comprised of 15 math expressions. Initially, they were asked to examine the grid and were informed that this portion of the survey involved classification. Following this explanation, participants were then asked to select one expression to serve as a model. After selecting this model expression, on a subsequent screen they selected other expressions from the grid that they perceived as falling into the same category as the original model. Participants were informed that they were permitted to select and deselect expressions at will until they were satisfied with their choices. (see Appendix C, D and E). This same categorization task was then administered a second and a third time. In each of these three iterations, participants were presented with the same grid of 15 expressions, and decided which of the remaining 14 expressions were similar to the model.

Questionnaire Measures

A series of electronic survey questions were also administered. This questionnaire portion of the study protocol incorporated 47 questions drawn from published measures and scales adapted for this study. These scales included a modified 14-item Personal Need for Structure

Scale (Thompson et al., 1989) adapted for mathematics, with 3 additional embedded questions taken from the Implicit Theory Scale (Rattan et al., 2012), adapted by the authors to specifically target mathematics attitudes (see Appendix F); and the 30 item Mathematics Anxiety Rating Scale (Suinn, 2003) known as the MARS-Brief. Both scales were presented as discrete subsections, allowing for randomization of item order. In addition to these questions, basic demographic information was collected, asking participants to indicate their gender identification, class year, age and race/ethnicity, along with their declared or projected major and, if applicable, their declared or projected minor.

Procedure

As participants entered the testing room, they were greeted, thanked for their willingness to participate, and were seated around a large, oval table. The experimenter then offered an oral overview of the session, informing participants that the study would be completely computer administered, focusing on attitudes towards mathematics. Participants were informed that they were free to skip questions should they be made to feel uncomfortable, or otherwise not wish to answer. It was explicitly stated that participants could withdraw from the study at any time for any reason, without forfeiting credit or compensation for their participation. They were informed that there would be no identifying information linking their responses with the surveys, ensuring that all responses would remain anonymous. After agreeing to participate, participants signed a written consent form distributed prior to the start of the session. Participants were then seated in front of computers with preloaded surveys, where they remained for the duration of the study. At the end of the session, they received a written debriefing describing in depth the nature of the study, along with contact information for additional inquiries.

Results

Overview. This study centered on the investigation of specific factors that might serve to either inhibit or encourage accurate mathematical reasoning. The hypotheses that drove this investigation were loosely based on the social psychological literature demonstrating that when meeting new people or faced with complex social situations, the majority of individuals tend to engage in stereotyping. This tendency to oversimplify when processing complex, nuanced social information does, in fact, allow for a decrease in effort expenditure but it can also lead to costly errors. Persons high on an individual difference variable measuring the cognitive need for simple structure have been shown to be exceptionally prone to oversimplify the person perception process and characterize others using indiscriminately broad groupings (Neuberg & Newsom, 1993). The primary hypothesis tested in this study was whether math anxious students would demonstrate a similar tendency to organize mathematical information into an artificially simple structure. In addition, this study explored whether beliefs about the origin of math intelligence as being either malleable or fixed would covary with math anxiety, as well as the need for simple structure.

Questionnaire Measures. The Math Anxiety Rating Scale, known as the MARS-Brief (Suinn, 2003) provided continuous level data, with higher values indicating higher levels of math anxiety. The Cronbach's alpha reliability of this 30-item measure was 0.93. Similarly, scores on the Personal Need for Structure Scale (Thompson et al., 1989) adapted for mathematics, produced continuous level data, with higher values indicating a greater tendency to impose a simplified structure. The Cronbach's alpha reliability of this 14-item Personal Need for Structure measure was 0.85. Scores on the Implicit Theory Scale (Rattan et. al, 2012), adapted by the author to specifically target mathematics attitudes were conceptualized as categorical data, with higher values indicating the propensity to view mathematical ability as fixed (entity perspective), and lower values indicating the belief that math intelligence is malleable (incremental perspective). The Cronbach's alpha reliability of this 3-item measure of implicit theory was 0.90.

Simple Structure, Math Anxiety, and the Implicit Theory Adopted. The primary hypotheses explored the relation between the need for simple structure, math anxiety, and the adoption of an entity theory perspective on the origin of math intelligence. The hypothesis that math anxious individuals would be especially prone to exhibit a preference for simplified, indiscriminately broad categorical thinking when faced with mathematical complexity was strongly supported. A Pearson correlation analysis revealed a highly significant positive relation between participants' predispositions towards math anxiety, as measured by the Math Anxiety Rating Scale, and the tendency to adopt a simplified, broad categorical approach to organizing mathematical content, as measured by the Personal Need for Structure Scale adapted for attitudes towards mathematics, $r\,(N = 97) = .61$, $p < .001$. Participants who were high in math anxiety were also predicted to espouse the belief that mathematical ability is relatively fixed or determined at birth, hallmarks of an entity perspective on the origin of math intelligence. This hypothesis was also supported. A Pearson correlation analysis demonstrated a significant positive relation between participants' scores on the Implicit Theory Scale and the Math Anxiety Rating Scale, $r\,(N = 97) = .31$, $p = .002$. Lastly, it was hypothesized that those who believed math intelligence is fixed would be more apt to seek a simplified structure when engaged in mathematical thinking, while participants who believed that math intelligence is more malleable would tend to adopt a more nuanced, and detailed approach to mathematical computation and reasoning. This hypothesis, too, received support. A Pearson correlation analysis revealed a significant positive relation between participants' scores on the Implicit

Theory Scale and their scores on the Personal Need for Structure Scale adapted for attitudes towards mathematics, $r\,(N = 97) = .39$, $p < .001$.

Individual Difference Variables and the Desire to Major in Math. Investigating further, math anxiety, the tendency to seek a simplified structure, and the adoption of an entity theory perspective were each found to covary with students' propensities to major or minor in math-intensive disciplines. A *t*-test showed that the MARS scores earned by participants who chose to major or minor in math intensive disciplines ($M = 56.59$, $SD = 15.24$) were significantly lower than the scores earned by those who chose to major or minor in less math intensive disciplines ($M = 67.80$, $SD = 18.52$), $t\,(86) = 2.32$, $p = .023$. Similarly, a *t*-test comparing the simple structure scores earned by participants representing these two academic major/minor groups revealed that scores earned by participants who chose to major or minor in math-intensive disciplines ($M = 48.07$, $SD = 9.09$) were significantly lower than scores earned by those who chose to major or minor in less math-intensive disciplines ($M = 58.57$, $SD = 10.88$), $t\,(86) = 4.48$, $p < .001$. Finally, a chi-square test of independence showed that implicit theory adopted[i], and the decision to major or minor in a math-intensive discipline were dependent, $\chi^2\,(1, N = 88) = 4.21$, $p = .04$, demonstrating that entity theorists were less likely than incremental theorists to enter math-intensive disciplines. Taken together, these results indicate that those study participants who scored high on math anxiety, sought simple structure in mathematics, and/or adopted an entity theory perspective on the origin of math intelligence were significantly less likely to major or minor in a math-intensive discipline.

Incremental Step Tasks. Two triangle-counting tasks were presented in sequence, and each participant's effort expenditure was measured in terms of initial accuracy, ultimate accuracy, and total response time. The initial, simpler triangle contained within it eight smaller triangles; while the second, more complex triangle contained 26 smaller triangles. Across both the simpler and more complex trials, participants were asked to indicate the total number of triangles they saw. If their initial response was incorrect, there were no restrictions placed on the number of additional attempts participants could make.

Math Anxiety, Effort Expenditure and Triangle Task Success. Math anxious individuals were found to be less likely to answer the initial, simpler triangle task question correctly on the first attempt, and were also less likely to successfully complete the simpler triangle task. An independent *t*-test showed that the MARS scores earned by participants who correctly answered the easier of the two triangle tasks on their first attempt ($M = 62.94$, $SD = 16.48$) were significantly lower than the scores earned by those whose initial answer was incorrect ($M = 76.06$, $SD = 19.35$), $t(95) = -2.89$, $p = .005$. Further, a *t*-test comparing the MARS scores of participants who were successful at solving the simpler triangle task (whether they made one or multiple attempts) ($M = 63.76$, $SD = 16.54$) to the scores of participants who failed to solve the task ($M = 87.67$, $SD = 20.18$) showed a highly significant difference between groups, $t(95) = -3.39$, $p = .001$, with math anxiety scores for those who were ultimately unsuccessful at this task considerably higher than the scores earned by those who were successful. However, math anxious participants' reduced rate of success was not due to a lack of effort, as measured by time spent on task. A *t*-test comparing math anxiety scores earned by participants spending more time ($M = 64.90$, $SD = 18.20$) or less time ($M = 65.58$, $SD = 17.20$) on task (median split) revealed no significant between-group differences, $t(95) = .19$, $p = .85$.

The second, more challenging triangle task revealed that when task difficulty increased, math anxious participants were no more or less apt to produce a correct answer on the first or second attempt than were their less math anxious peers, nor were they more or less likely to answer correctly on their final attempt. An independent *t*-test showed that the MARS scores earned by participants who correctly answered the more challenging of the two triangle tasks on their first attempt ($M = 65.08$, $SD = 18.03$) were not significantly different than the scores earned by those whose initial answer was incorrect ($M = 65.26$, $SD = 17.69$), $t(95) = -.03$, $p = .97$. Additionally, MARS scores earned by participants who correctly answered the second triangle task on either their first or second attempt ($M = 63.72$, $SD = 16.17$) were not significantly different than the scores earned by those whose first or second answer was incorrect ($M = 65.58$, $SD = 18.03$), $t(95) = -.40$, $p = .69$. Finally, an independent *t*-test revealed that on this more challenging task, the MARS scores earned by participants who were correct on their final attempt ($M = 62.83$, $SD = 14.27$) were not significantly higher or lower than scores earned by those who were not correct on their final attempt ($M = 66.93$, $SD = 19.61$), $t(95) = -1.13$, $p = .26$. An independent *t*-test comparing the MARS scores earned by participants spending more ($M = 62.76$, $SD = 18.01$) or less time ($M = 67.77$, $SD = 17.06$) on the second, more complex triangle task (median split) showed no significant difference between groups, $t(95) = 1.41$, $p = .16$.

Simple Structure, Effort Expenditure and Triangle Task Success. When compared to their peers scoring low on the Personal Need for Structure Scale (PNS) adapted for mathematics, individuals scoring high were found to be equally likely to answer the initial, less challenging triangle task question correctly on the first attempt. They were also equally successful at completing the initial triangle task. An independent *t*-test showed that the PNS scores earned by participants who correctly answered the easier of the two triangle tasks on their first attempt ($M = 54.39$, $SD = 10.85$) were not significantly different than the scores earned by those whose initial answer was incorrect, ($M = 58.29$, $SD = 11.57$), $t(95) = -1.33$, $p = .19$. Exploring further, an independent *t*-test comparing PNS scores of participants who were successful at solving the simpler triangle task (whether they made one or multiple attempts) ($M = 54.69$, $SD = 10.84$) to the scores of participants who failed to solve the task

(M = 61.00, SD = 13.05) also did not show a significant difference between groups, t (95) = -1.37, p = .18. Participants who scored high on the PNS exhibited similar rates of effort expenditure on the less complex triangle task, as measured by time spent on task. An independent t-test comparing PNS scores earned by participants spending more (M = 55.91, SD = 11.46) or less time (M = 54.23, SD = 10.60) on task (median split) revealed no significant between-group differences, t (95) = -.75, p = .46.

When compared to their peers scoring low on need for simple structure, participants who sought simple structure were also no more or less apt to produce a correct answer on a first, second or final attempt on the complex triangle task. An examination of the PNS scores earned by participants revealed no significant difference between those who were correct on their first attempt (M = 51.79, SD =12.77) and those who were not (M = 55.41, SD = 10.77), t (95) = -1.11, p = .27. Similarly, PNS scores earned by individuals who correctly answered the second triangle task on either their first or second attempt (M = 52.25, SD = 12.10) were not significantly different than the scores earned by those whose first or second answer was incorrect (M =55.72, SD = 10.73), t (95) = -1.21, p = .23. Finally, an independent t-test revealed that on this more challenging task, the PNS scores earned by participants who were correct on their final attempt (M = 53.54, SD = 11.97) were not significantly higher or lower than scores earned by those who were not correct on their final attempt (M = 56.16, SD = 10.63), t (95) = -1.16, p = .25. Focusing on effort expenditure, an independent t-test comparing the PNS scores earned by participants spending more (M = 54.05, SD = 11.70) or less time (M = 56.13, SD = 10.32) on the second, more complex triangle task (median split) showed no significant difference between groups, t (95) = .93, p = .36.

Entity Theory, Effort Expenditure and Triangle Task Success. Entity theorists were neither found to be more nor less likely than their incremental theorist peers to answer either of the two triangle tasks questions correctly on the first attempt, and were equally likely to successfully complete both triangle tasks on their final attempt. A chi-square test of independence showed that implicit theory (incremental theory/entity theory) and the likelihood of answering correctly on the first attempt on either the first or second triangle task were independent, χ^2 (1, N = 97) = .17, p = .68 and χ^2 (1, N = 97) = .25, p = .62, respectively. Similarly, a chi-square test revealed that the implicit theory adopted on the origin of math intelligence and the propensity towards answering the first or second triangle question correctly on the final attempt were also independent, χ^2 (1, N = 97) = .59, p = .44 and χ^2 (1, N = 97) = 1.17, p = .28, respectively. Additionally, entity theorists demonstrated the same level of effort expenditure as did their incremental theorist peers across both triangle tasks. A chi-square test showed that implicit theory adopted and time spent on either the first or second task (median split) were independent, χ^2 (1, N = 97) = .01, p = .92 and χ^2 (1, N = 97) = .26, p = .61, respectively.

Additional Considerations Regarding Effort Expenditure and Triangle Task Success. After these analyses were complete, a final question remained— was there a significant relation between effort expenditure and level of success on the second, more challenging triangle task? A t-test comparing the amount of time spent by participants whose final answers were correct (M = 73.98, SD = 56.04) or incorrect (M = 45.63, SD = 30.06) revealed a highly significant between-group difference, t (54.78) = 2.92, p = .005. Those who spent more time on the second, more complex triangle task were significantly more likely to answer correctly. The decision to major or minor in a math-intensive discipline and the ability to answer the second, more challenging triangle question correctly were also found to be dependent, χ^2 (1, N = 88) = 5.61, p = .018. Those who did not elect to major or minor in math intensive disciplines were less likely to answer the second triangle task correctly. Driving this result may have been the fact that there was a marginally significant difference between math (*M* = 69.82, *SD* = 60.57) and non-math majors/minors (*M* = 50.13, *SD* = 35.10) in the amount of time each group devoted to the second, more challenging triangle task, $t(86) = -1.928$, $p = .057$, with those pursuing math-intensive disciplines spending more time on task.

Behavioral Measure of Simple Structure. In addition to the self-report measure of personal need for structure, a behavioral measure of this tendency was administered and analyzed. Participants were presented with three categorization tasks, and received either a score of one or two on each categorization trial, indicating the presence or absence of sort complexity in their classification approach. Independent *t*-tests comparing the MARS scores of participants who demonstrated the tendency to adopt an especially simplified categorization approach across the first (*M* = 64.84, *SD* = 12.38), second (*M* = 67.00, *SD* = 19.37), or third trial (*M* = 65.95, *SD* = 17.48) to the scores of those who demonstrated a more complex approach across the first (*M* = 66.48, *SD* = 12.78), second (*M* = 61.04, *SD* = 12.47), or third trial (*M* = 60.71, *SD* = 18.76) showed no significant difference between groups, $t(90) = -.41$, $p = .68$, $t(91) = 1.02$, $p = .31$, and $t(59.53) = 1.70$, $p = .09$, respectively. Importantly, however, participants' scores on the published self-report measure of Personal Need for Structure (Thompson et al., 1989) did not appear to be predictive of their performance on this behavioral measure of need for simple structure developed specifically for this study. Independent *t*-tests comparing PNS scores of participants who demonstrated the tendency to adopt a simplified categorization approach on the first (*M* = 54.89, *SD* = 12.29), second (*M* = 55.24, *SD* = 11.23), or third trial (*M* = 55.67, *SD* = 11.41) to the scores of those who demonstrated a more complex approach on the first (*M* = 55.02, *SD* = 8.51), second (*M* = 52.61, *SD* = 10.34), or third trial

(M = 51.91, SD = 9.01) showed no significant difference between groups, $t(78.83) = -.05$, $p = .95$, $t(91) = .82$, $p = .42$, $t(89) = 1.43$, $p = .16$, respectively.

Discussion

The present study provided significant empirical support for the hypothesis that math anxious individuals will score especially high on the need for simple structure. This investigation makes a unique and important contribution to the psychological literature in that this finding serves to bridge the social stereotyping research exploring individual differences in the predisposition towards indiscriminately broad categorical thinking in social situations with the tendency towards the oversimplification of nuanced information when engaged in mathematical reasoning. In the same way that some persons are driven to impose an inappropriately simple structure in social realms, other individuals may take similar cognitive shortcuts when confronted with mathematical complexity. And this maladaptive strategy may interfere with well-reasoned mathematical concept integration.

Relations between study participants' need to impose a simplified structure, level of math anxiety and implicit theory of math intelligence adopted were explored. Consistent with hypotheses, individuals high in the need for simple structure in mathematics were found to be high in math anxiety; and those high in simple structure needs were also more likely to adopt an entity theory perspective on math intelligence. Further, again congruent with hypotheses, participants high in math anxiety were also more likely to adopt an entity theory perspective on the origin of math intelligence. Finally, as predicted, participants who sought simple structure, scored higher on the measure of math anxiety, and/or adopted an entity theory perspective on the origin of math intelligence were significantly less likely to major or minor in a math intensive discipline.

However, contrary to hypotheses, there was no systematic relation found between math anxiety scores and the tendency to impose a simple structure, as measured by a behavioral categorization task developed specifically for this study. This categorization task was loosely based on an established measure of sort simplicity and complexity (Neuberg & Newsom, 1993); however, the transition from the original experimenter-administered format to a computer-administered task coupled with a switch of focus to mathematical content necessitated major modifications to the original categorization process. The fact that scores on this adapted behavioral measure failed to correlate with scores on the published paper-and-pencil inventory of need for structure calls into question the validity of this newly constructed assessment tool.

This investigation was also designed to target directly observable behavioral effects of the need for simple structure, mathematics anxiety, and implicit theory adopted concerning the origins of intelligence on the ability to solve two progressively challenging triangle-counting tasks. Math anxious individuals were less likely than their less anxious peers to answer the initial, simpler question correctly; however, they were willing to devote the same amount of time to this problem as were those scoring lower in math anxiety. When task difficulty was increased in the second triangle task, math anxious participants were no more or less likely than their non-anxious peers to answer this question correctly, and both groups again devoted the same amount of time to this task. No significant between-group performance differences emerged between those high and low in need for simple structure on either of these triangle tasks with respect to time spent or correctness of answer; similarly, entity and incremental theorists were equally successful on each of the triangle tasks, and both groups devoted comparable amounts of time to each task. However, participants choosing math-intensive majors and minors were found to spend significantly more time on the second more demanding task, and this group was also more apt to answer it correctly.

Taken together, these findings point to the possibility that when confronted with complex mathematical concepts and procedures, individuals high in the need for simple structure, and math anxious individuals in general, might derive considerable benefit from instructional approaches that are based on the presentation of mathematical concepts via a series of progressively more complex tasks. Although, when compared to their less anxious peers, math anxious individuals were less successful at the first triangle task, they were able to close these initial achievement gaps in the second triangle task. Further, those high in the need for simple structure were no more or less able than their peers to complete the second more difficult triangle task. Taken together, these findings may well have been driven by the fact that participants had just a few minutes before been introduced to the first, less difficult triangle problem. Those attempts to solve the initial problem may have helped participants high in math anxiety and the need for simple structure to build a conceptual framework with which to approach the second more challenging task (see Appendix G). If, in fact, exposure to the earlier, simpler but conceptually similar problem facilitated the development of a strategy that could later be applied to other more difficult questions, it is easy to understand how math anxious individuals and students high in the need for simple structure might especially benefit from a purposeful, planned and systematic presentation of increasingly complex models.

While no significant between-group performance differences emerged between entity and incremental theorists on either triangle task, it is important to remember that participants in this study were recruited at an all-women's college. The adoption of an entity theory perspective on intelligence has proven inhibitive when beliefs about oneself are derived or reaffirmed by negative social stereotypes that trivialize the cognitive capacity of affiliated sub-groups (Smith, Lewis, Hawthorne, & Hodges, 2012). Theoretically at least, ingrained cultural beliefs that women and girls are inferior at mathematical endeavors would serve as just such a cognitive barrier to effort expenditure and subsequent success in mathematical pursuits (Smith et al., 2012). However, in the presence of favorable perceptions and stereotypes about an affiliated group, the adoption of an entity theory perspective may serve as a benign or even potentially motivating factor (Mendoza-Denton, Kahn, & Chan, 2008). While women and girls in co-educational classrooms may be especially susceptible to the adoption of a defeatist attitude towards their own mathematical ability, it is plausible that these stereotypes are neutralized or even nonexistent in single-sex classrooms. In this investigation, incremental and entity theorists' comparable levels of success on the triangle task may indicate that attendance at a women's college can assuage some of the more maladaptive consequences often associated with the adoption of an entity theory perspective.

When designing this investigation, one primary concern was that the inclusion of a mathematical skills measure could potentially elicit math anxiety in some study participants. While one approach might have been to always present these math problems at the end of the study session, the benefits of a counterbalancing of order of measure presentation were thought to outweigh the cons. The two triangle problems were intentionally selected because they presented enough complexity to pose a sufficient challenge for all study participants but required only simple addition skills for successful completion. These efforts to minimize the provocation of math anxiety allowed for a counterbalanced presentation of all study measures. Therefore, while these triangle tasks were somewhat limited in scope and perhaps in generalizability as well, they served the purpose for this preliminary, exploratory study. Future investigations in this area will need to incorporate tasks that tap a wider range of mathematical skills. When Harris and Carlton (1993) used the Scholastic Aptitude Test (SAT) as a primary dependent measure of confidence and competence in math, gender differences in proficiency emerged within the SAT's geometric, algebraic and arithmetical subsections. Harris and

Carlton's (1993) investigation, and others like it, provides strong evidence that, when compared with their male peers, girls and women underperform in some mathematical sub-areas, though not all. In turn, many girls and women have been found to be hesitant to enter math-based disciplines. Therefore, in future explorations of mathematics anxiety and related constructs, it will be important to introduce a sampling of mathematical problems that span numerical and variable-based skills as well as spatial reasoning.

In addition to diversifying the mathematical sub-areas to be tested, future investigations might also be designed to explore alternative avenues through which investigators might more aptly observe and quantify maladaptive categorization techniques born of the tendency to impose oversimplified classification strategies. Targeted studies are needed to identify and observe the behavioral expressions and consequences of the need for simple structure in the mathematics classroom. Investigations will also be needed to determine whether, in fact, the ordered presentation of a series of conceptually similar but progressively more complex tasks can consistently promote persistence in problem solving and ultimate success for participants who are high in math anxiety and/or the need for simple structure. In other words, further study is needed to determine whether exposure to a series of intermediary steps in the form of simpler problems that rely on the same set of conceptual elements underlying the more challenging tasks to follow may potentially provide those with math anxiety and those who require simple structure with the experience and confidence they need to progress towards what they perceive to be especially difficult mathematical material. In the laboratory and the classroom, testing procedures drawing from arithmetic, algebra and geometry and incorporating varying levels of difficulty would allow for a rich array of potential patterns of effort expenditure and performance outcomes.

Future studies must also be designed to explore issues of directionality and/or causality among the various individual difference variables investigated here. The present study revealed that those scoring high on math anxiety also tended to score high on the need for simple structure. It seems plausible that the imposition of simple structure may serve as a coping mechanism, providing a cognitive recourse for math anxious individuals who are confronted with difficult mathematical material and are unable to practice avoidant strategies (e.g., simply refusing to enroll in courses with math-based curriculum). This inappropriately simple approach, whether conscious or unconscious, might be taken in an effort to reduce the cognitive discomfort associated with processing mathematical complexity. Teaching techniques or curricula designed to address the specific cognitive needs and responses of math anxious students and those high on the need for simple structure might serve to mitigate math anxiety and facilitate students' procurement of a solid mathematics foundation. Clearly, additional research is needed in order to determine whether causality between these individual difference variables can be assigned.

For many students of all ages, the study of mathematics can feel like a hopelessly complex list of rules to be memorized. Math anxious learners may be especially affected by the adoption of this perspective, given math anxiety's demonstrated effect on the diversion of working memory resources (Kellogg et al., 1999). When students can be helped to understand and master the underlying principles of mathematics at the foundational level, their mathematics learning becomes far more intuitive and their reliance on rote memorization is greatly reduced. Importantly, persons high in the need for simple structure have not been shown to score low in the need for cognition (Neuberg and Newsom, 1993), operationalized as the extent to which an individual derives enjoyment from critical thinking, posing questions such as: "I find satisfaction in deliberating hard and for long hours" (Cacioppo & Petty, 1982).

Further, in an investigation carried out by Levy et al., (1998), participants' scores on measures of implicit theory were not found to covary with scores on Cacioppo and Petty's Need for Cognition Scale (1982). These findings demonstrate that persons high in the need for simple structure and those who adopt an entity theory perspective with respect to math ability are no more or less capable of handling mathematical complexity. For mathematics educators, the challenge is to determine how to gradually increase the complexity of material presented without eliciting anxiety. As demonstrated in the present study, the introduction of a conceptual blueprint for complex tasks to follow could potentially build student confidence and encourage perseverance in problem solving even for learners who experience math anxiety, seek simple structure, and/or adopt an entity theory perspective.

Categorical thinking is not inherently maladaptive; drawing parallels between past and present experiences enables swift decision making and allows for a more successful navigation of a complex world (Tajfel, 1981). When complexity levels rise, reliance on heuristic processing similarly increases; however, crucial information may be lost when the categories formed as part of this process are inaccurate or incomplete (Bodenhausen & Wyer, 1985). Persons high in the need for simple structure may be especially prone to forge indiscriminately broad connections in an effort to reduce confusion and assuage anxieties (Neuberg & Newsom, 1993). This preliminary investigation demonstrated the connection between mathematics anxiety, the need for simple structure, and the adoption of an entity theory perspective in mathematics. Further investigation is now needed to identify concrete instructional practices that will meet students' cognitive needs as they encounter increasing levels of mathematical complexity.

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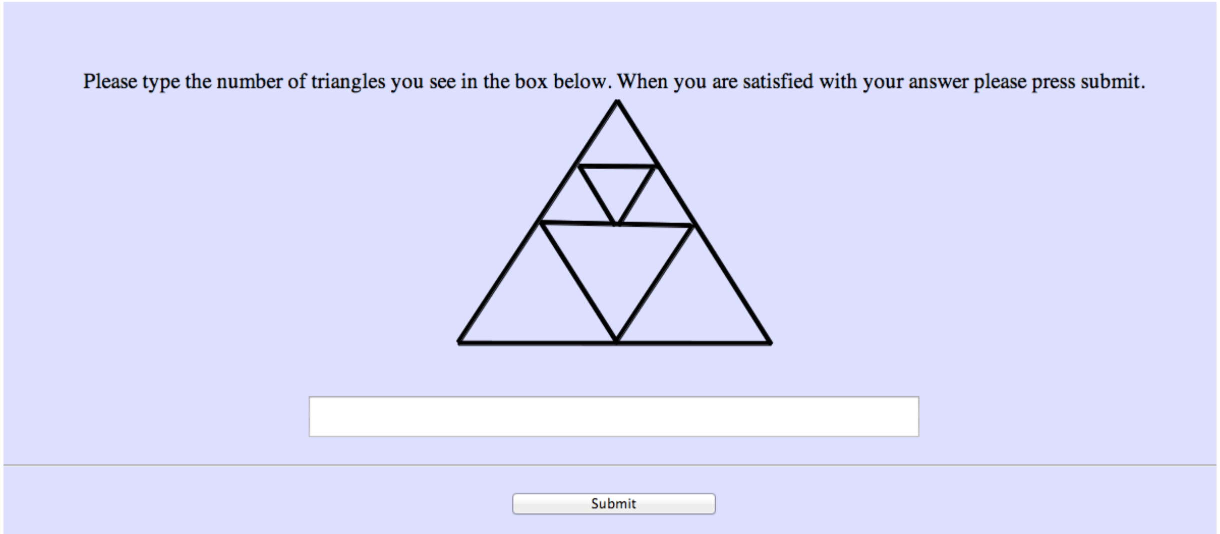
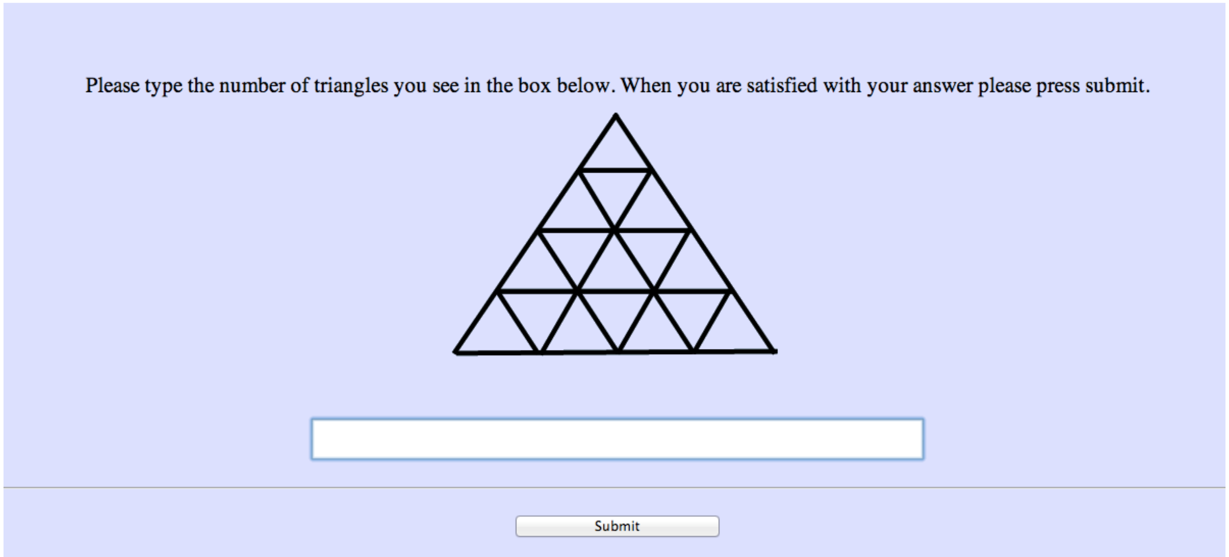
Appendix A: Incremental Steps Task; Triangle Task One



Appendix B: Incremental Steps Task; Triangle Task Two



Appendix C: Categorical Thinking, First Task Screen

To begin, click any one expression in the grid below!

This first expression you select will become the "model expression." Once it has been selected, the box behind the "model expression" will change color. To unselect, click the box again, returning it to its original color.

After you've selected your "model expression," please press submit.

2π	$\cos(2\pi)$	121^2	$33x$	$\frac{2x}{11}$
$\frac{11}{33}$	$\int 2x\,dx$	$\cos(x)$	$2+2^2$	$\sin(\pi)$
$2x$	$\frac{11^2}{2}$	$\sin(x+2)$	$(2x-2)^2$	$9+5$

Submit

Appendix D: Categorical Thinking, Second Task Screen

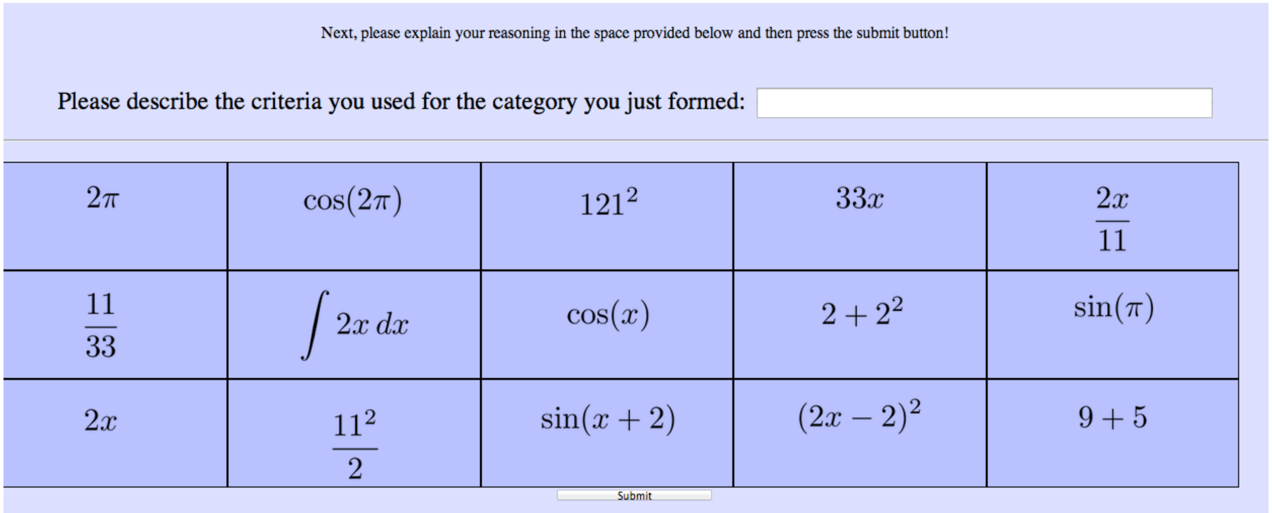
Next, click on one or more expressions that you believe appear similar to this model expression.

To classify an expression as similar, scroll over it with your mouse and select by clicking once. To unselect, click the box again, returning it to its original color. You may select as many or as few expressions as you feel are similar to the model expression. These expressions will also change color.

2π	$\cos(2\pi)$	121^2	$33x$	$\frac{2x}{11}$
$\frac{11}{33}$	$\int 2x\,dx$	$\cos(x)$	$2+2^2$	$\sin(\pi)$
$2x$	$\frac{11^2}{2}$	$\sin(x+2)$	$(2x-2)^2$	$9+5$

Submit

Appendix E: Categorical Thinking, Third Task Screen


Next, please explain your reasoning in the space provided below and then press the submit button!

Please describe the criteria you used for the category you just formed:

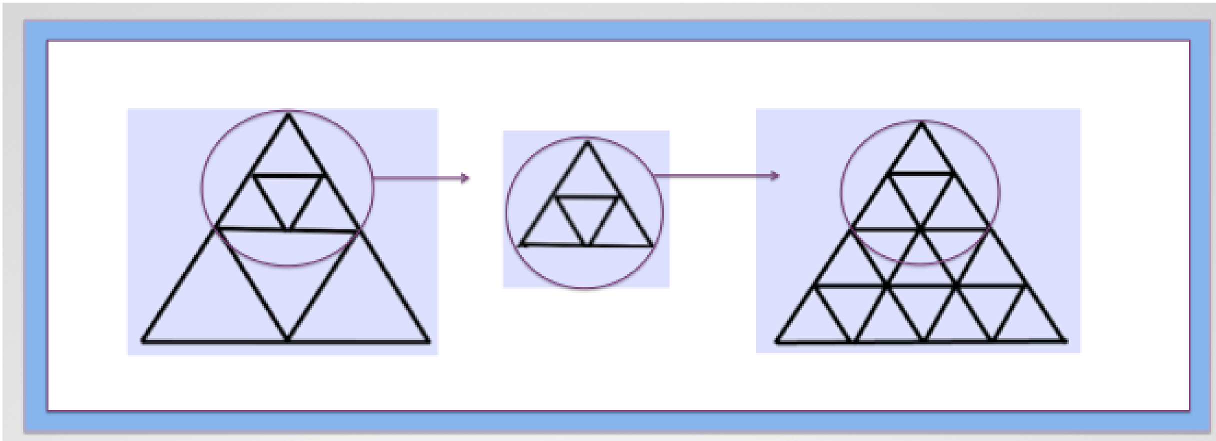
2π	$\cos(2\pi)$	121^2	$33x$	$\frac{2x}{11}$
$\frac{11}{33}$	$\int 2x\,dx$	$\cos(x)$	$2+2^2$	$\sin(\pi)$
$2x$	$\frac{11^2}{2}$	$\sin(x+2)$	$(2x-2)^2$	$9+5$

Submit

Appendix F: PNS Scale, adapted for mathematics, with questions embedded from the Implicit Theory Scale

1. It upsets me when I encounter a math problem unlike any problems I have encountered in the past.
2. When solving a math problem, I am not bothered when I hit a dead end and have to adopt a new strategy.
3. When approaching math problems, I enjoy having a clear and structured set of instructions.
4. I feel better about math when I am able organize mathematical rules and concepts into simple, overarching structures.
5. I have a certain amount of math intelligence, and I can't really do much to change it.
6. I find that doing math problems with a series of clear and simple steps to their solution feels boring.
7. I don't like working on math problems when I am uncertain about whether I can get the correct answers.
8. I hate it when I have to change my approach to solving a particular problem.
9. I hate it when math professors are unpredictable.
10. To be honest, I can't really change how intelligent I am in math.
11. I find that having a consistent approach to math problems enables me to enjoy working math problems more.
12. I enjoy the exhilaration of being presented with math problems unlike any I've ever seen before.
13. I become uncomfortable when the rules are not presented clearly in math class.
14. I don't like working with variables
15. I am fascinated by math problems that can be approached in multiple ways.
16. I don't like being presented with unfamiliar math symbols.
17. I can learn new things, but I can't really change my basic math intelligence.

Appendix G: Key Conceptual Leap



[i] Entity and incremental theorists are often identified as those falling one standard deviation above or below the scale mean, (Rattan et al., 2012); in the present study, a median split served to maintain a meaningful sample size across each comparison.