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Math = Male, Me = Female, Therefore Math ≠ Me

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College students, especially women, demonstrated negativity toward math and science relative to arts and language on implicit measures. Group membership (being female), group identity (self = female), and gender stereotypes (math = male) were related to attitudes and identification with mathematics. Stronger implicit math = male stereotypes corresponded with more negative implicit and explicit math attitudes for women but more positive attitudes for men. Associating the self with female and math with male made it difficult for women, even women who had selected math-intensive majors, to associate math with the self. These results point to the opportunities and constraints on personal preferences that derive from membership in social groups.

When the *New York Times* interviewed the three living female descendants of Elizabeth Cady Stanton, the focus was not on the indisputable mark she had left on American society but rather the effect she had had on her own family (Bumiller, 1998). The accomplishments of this housewife who organized the historic 1848 Seneca Falls convention to demand the right of women to vote were visible even in the careers of her own daughters and their daughters. The youngest of the women interviewed, also named Elizabeth and 13 years old at the time, said that she would like to be an engineer or an architect, following in the footsteps of her grandmother and great-grandmother. Although she showed cognizance of the hurdles that stood in the way of her ancestor's battle for a simple equality, she was optimistic about the present, remarking that now "anything's possible for anyone" (p. B6).

The idea that anything ought to be possible for anyone is the foundation of many proclamations of equality, such as the constitutions of nations and their legal codes. Yet, as even a superficial historical glance reveals, demarcations of humans into social groups and their unequal access to resources have been the primary impetus for theory and action to achieve social justice. As psychologists, we are interested in the mechanisms by which aspirations for equality are undermined—not by a lack of legal protection but in the more basic social and mental processes that determine individual preferences and choices. The operation of such processes can be subversive—they appear to reflect a free and individually determined choice when in fact they reflect group membership, the strength of identity with the group, and beliefs about the capability of the group.

In this article, we focus on the fundamental dichotomy of gender as we investigate preferences for mathematics (and science) versus the arts (and language). The covariation between gender and orientation toward math and science is well known: Men are assumed to be and demonstrated to be more inclined to participate and excel in math and science, at least as compared with women (National Science Foundation [NSF], 1996). If membership in the groups *male* or *female* is associated with differing preferences and choices, no legal remedy to address such disparities is even at issue—an individual, it appears, freely chooses to participate in a system of self-imposed social segregation on the basis of a personal preference.

The appearance of free choice, however, does not preclude the possibility that group membership and group expectancies have a subtle relationship with personal preference and choice. Thoughts and feelings that occur outside conscious awareness or control may provide a basis for understanding the relationships among personal preferences and choices, on the one hand, and group identity and stereotypes, on the other (Greenwald & Banaji, 1995; Greenwald et al., 2002).

A large body of literature already exists on the math–gender relationship, and it has used conscious, self-report measures of attitudes and identity. In this research we conduct the first test using implicit measures of math attitude, math identity, math–gender stereotypes, and gender identity to examine relationships among these constructs. As such, the primary goal of this research is to establish the nature of these relationships, the consistency of empirical findings, and the generalizability across a variety of stimulus presentations. For example, does implicit identity with the group *female* relate to preferences for math?

The number of possible relationships among these variables is large, encouraging us to select a theoretical framework a priori. For the theoretical background, we use the principles of cognitive consistency theory. Greenwald et al. (2002) have recently identified the utility of cognitive consistency theories, especially the

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principles of Heiderian balance (Heider, 1958). The main principles we rely on are associations between self and social group and the movement to balance between cognitive–affective systems. Group associations between math and gender (i.e., *math–gender stereotype*) and between gender and self (i.e., *gender identity*) may relate to more personal associations between math and self (i.e., *math identity*) and between math and positive attributes (i.e., *math attitude*). For example, stronger associations between math and *male* should lead to weaker associations between math and self for women but stronger associations between math and self for men. We also examine the relations between these components of implicit social cognition and their more frequently researched counterparts—self-reported or explicit attitudes, identity, and stereotypes. The nature of the relationship between implicit and explicit modes of assessment may provide clues to how each shapes orientations toward math and how each mode of thinking can predict outcomes such as performance on standardized math examinations. Here we focus on four types of implicit associations of particular relevance for the study of gender and orientations toward math: (a) the association between the concept *math* and evaluation (good–bad; i.e., math attitude), (b) the association between math and the self (i.e., math identity), (c) the association between math and gender (male–female; i.e., math–gender stereotype), and (d) the association between self and gender (i.e., gender identity).

The Math–Gender Relationship

Across all domains that require mathematical expertise, women participate less than men do. As level of education increases, the ratio of female to male participants in math and related sciences declines. In high school, boys and girls participate equally in math and science[1] (NSF, 1996), but at the college level, women are poorly represented in math and math-intensive fields such as the physical sciences (34%), math/computer science (35%), and engineering (16%). This imbalance stands in contrast to strong female representation in less mathematically oriented sciences in college, such as psychology (73%), the social sciences in general (48%), and even the biological sciences (49%; NSF, 1996).

There is substantial evidence that gender differences in performance are associated with gender differences in participation. A meta-analysis of 100 studies found that although no gender differences in math test performance were noticed between boys and girls in elementary school, differences favoring boys were evident in high school (Cohen's $d = .29$; Cohen, 1988) and in college ($d = .32$; Hyde, Fennema, & Lamon, 1990). These differences were more dramatic in studies using highly selective samples ($d = .54$) or gifted children ($d = .41$; Hyde, Fennema, & Lamon, 1990). Among the largest observed gender differences are those observed on the math portion of the SAT, an important criterion for admission to college (Hyde, Fennema, & Lamon, 1990). Although a national survey detected that the difference in boys' and girls' scores had diminished somewhat since 1984, a gap of 41 points still persists ($M = 500$, $SD = 100$; girls, $M = 460$; boys, $M = 501$; NSF, 1996). Many models that seek to explain gender differences in math achievement and participation view math attitudes as important precursors to an understanding of those differences (Eccles, 1987; Fennema, 1985; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Leder, 1986; Parsons, Adler, & Meece, 1984). Relative to men, women report more negativity toward math, less identification with math, and less confidence in doing math, but those differences are relatively small (Hyde, Fennema, Ryan, et al., 1990).

In addition to attitudes, most models of orientations to math emphasize social factors such as gender stereotypes in predicting performance and participation (Eccles, 1987; Fennema, 1985; Leder, 1986; Parsons, 1983, 1984; Steele, 1998). For example, Eccles (1987) has argued that observed gender differences are predominantly a function of academic course selection and subjective value placed on the tasks and that these are influenced by factors such as sex roles, self-schemas, attributions for success, and anticipated task demands. Emphasizing social learning of the stereotype that math is not a domain in which girls can excel, the theory pinpoints expectancies and self-fulfilling prophecies as the psychological mechanisms that result in girls turning away from math and related subjects.

Despite the presumed importance of stereotypes for predicting participation and performance in such models, the evidence obtained with self-report measures increasingly suggests quite the opposite—widespread rejection of the stereotype that math is for men and not for women. In Hyde, Fennema, Ryan, et al.'s (1990) meta-analysis, both men's and women's ratings "fall on the portion of the scale indicating a rejection of stereotypes" (p. 310). The low endorsement of math–gender stereotypes in previous research may be explained by the exclusive use of self-report measures, which are likely influenced by conscious assumptions of egalitarianism in viewing social groups. Alternative measures to detect preferences that are not fully under conscious control and may even reside outside conscious awareness may prove to be useful to test theory and to reveal previously unexamined aspects of math–gender attitudes and stereotypes. In this research, we apply one such measure to understand the relationship among group membership, group identity, group stereotypes, and attitudes toward math. Specifically, we examine how preferences and choices often assumed to be a product of individual volition may be a reflection of group identity and knowledge about groups (stereotypes).

Assessing Implicit Attitudes, Identity, and Stereotypes

To measure implicit attitudes, identity, and stereotypes, we used a response competition task called the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998; Greenwald & Nosek, 2001; for reviews of the measurement and assessment of implicit, or automatic, evaluation, see Banaji, 2001, and Fazio, 2001). The task operates on the basis of a principle that it ought to be easier to pair concepts (e.g., any attitude object, e.g., *math* or *arts*) with attributes that have come to be associated through experience (e.g., the qualities of *good* or *bad*, *strong* or *weak*, *male* or *female*) than it is to pair concepts with attributes that are less or not at all associated. For instance, the concept *flower* and the attribute *pleasant* (e.g., represented by *wonderful*, *happy*, *rainbow*) ought to be easier to pair mentally than the concept *flower* and the attribute *unpleasant* (e.g., *disgust*, *hatred*, *gun*). The extent to which it is easier to pair *flower* + *pleasant* (in the presence of a

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[1] Physics is the single exception at the high school level in which boys participate more than girls do.

contrasting pair, e.g., *insect + unpleasant*) compared with the opposite pairings (e.g., *flower + unpleasant* and *insect + pleasant*), the stronger is the assumed positive implicit evaluation of flowers relative to insects. In this task, ease or strength of association is measured by the speed to respond to a type of pairing (e.g., *math + pleasant*) compared with another type of pairing (e.g., *math + unpleasant*).

A feature of the IAT measure is that preference for one concept (e.g., math) is assessed in relative comparison with preference for a second concept (e.g., arts). The presence and nature of the second contrasting category can shape the attitude that is revealed, and new research devoted explicitly to this question is available (Nosek & Banaji, 2001). The presence of a contrasting category can add predictive power in some research domains, especially with regard to assessments of attitudes, stereotypes, and identity when a direct comparison is relevant (e.g., male vs. female, Black vs. White; see Greenwald et al., 2002). In the present research, the presence of a contrasting category has particular relevance in that choices often occur in the company of alternatives. For example, a sophomore may be enjoying both her math and her history class but may choose to be a history major because, compared with math, she enjoys history more. But what should such a contrasting category be? This being the first test of implicit math–gender attitudes, we first used multiple contrasting categories (language, arts, letters) and established that a variety of contrasting categories produce stable implicit attitudes in theoretically predicted ways.

The studies described in this article, with some variations, compare math or science with arts or language. Arts/language is a natural contrasting category for math/science because it is used to delineate the landscape of higher education: Majors are divided into liberal arts and sciences (which vary dramatically in their emphasis of math), standardized tests such as the SAT have two subtests (verbal and math), and degrees are awarded on the basis of their comparative emphasis on the arts (Bachelor of Arts) or science (Bachelor of Science). Therefore, many of the choices undergraduates must make in developing a basis for a career (i.e., choosing a major) involve a basic distinction between math/science and arts/language. The effects described in this article are effects of math/science relative to arts/language, but, to simplify presentation, the results are generally described in terms of attitudes, identity, beliefs, or performance in regard to math (without repeated emphasis of the contrasting categories), except when the contrast categories are of particular interest.

Serendipitous Findings and a Preliminary Study

This research on implicit attitudes toward math emerged in part from a serendipitously detected effect in an unrelated investigation. Two studies were designed with the assumption that they would reveal a neutral baseline of the IAT with which other effects could be compared. The first study ($N = 24$) modified the initial task (Greenwald et al., 1998) by replacing names of flowers and insects with ordered sequences of digits (e.g., *3456*) and letters (e.g., *RSTU*). It was expected that responses to strings of digits and letters would show equal association with pleasant and unpleasant items—that is, that no difference in automatic attitude toward the two categories (i.e., digits, letters) would be observed. The data, however, did not conform to this expectation. On average, participants responded 71 ms faster when pairing letters and pleasant words than when pairing digits and pleasant words. In a second study ($N = 24$), the digit–letter dimension replaced the pleasant–unpleasant (rather than the flower–insect) dimension of the original design. Again, participants were 60 ms faster when giving a response to flower names and letter strings than when giving the same response to flower names and digit strings. Both studies produced unexpectedly more positive implicit evaluations of letters than of digits. The initial confusion caused by the observation of this unhypothesized effect prevented immediate realization that the task may be providing a measure of implicit attitudes toward numerical, mathematical concepts. When that light bulb at last illuminated, the new possibility was put to its first test in further analysis of the data from the two studies. The aim was to determine whether those studies had shown a difference between the male and female college students who participated in them, and indeed they did. In the first study, the implicit numerical dislike effect was −110 ms for women ($p = .05$), compared with −33 ms for men (larger negative numbers indicate stronger negative associations with digits than with letters; $p = .53$). In the second study, the corresponding figures were −81 ms for women ($p = .02$) and 23 ms for men ($p = .68$). This post hoc observation in two studies provided the basis for further examination of the gender difference as well as more complex theorizing about the relationship among mental components of attitudes, stereotypes, and identity.

We followed up on the serendipitous findings with a preliminary study to systematically investigate gender differences in implicit attitudes toward math. This study was designed to test whether gender differences in implicit math attitudes do exist and also to make certain that observed gender differences were at least partly a consequence of the concept of mathematics being activated and not due to the peculiarities of the categories of letters and digits.

In one task we contrasted math with language, using familiar concepts associated with math (e.g., *algebra*, *calculation*) and language (e.g., *book*, *sentence*; see the Appendix for a complete list of stimuli). In this math/language task, both men ($M = -71$ ms) and women ($M = -158$ ms) were faster to categorize math with pleasant words than math with unpleasant words, demonstrating negative implicit attitudes toward math relative to language; men: $t(36) = -3.51$, $p = .001$, $d = -0.59$; women: $t(36) = -6.20$, $p = 10^{-7}$, $d = -1.03$. In addition, women showed significantly stronger negativity toward math than did men, $F(1, 72) = 4.45$, $p = .04$, $d = 0.50$.

A second task in the same study varied the representation of the comparison category to ensure that the observed gender difference was not exclusively due to the comparison with language. Math was represented with equations (e.g., *3 + 4 = 7*; *6 * 2 = 12*), and the contrasting category consisted of names of unfamiliar geographic locations (e.g., *Tonga*, *Curacao*). We selected this contrasting category to give math a familiarity advantage as well as to use a category equally unfamiliar to women and men. The equations/places task also revealed an overall negative automatic evaluation of math (equations) relative to unfamiliar places, $F(1, 72) = -3.57$, $p = .06$, $d = -0.46$. Again, women showed negative automatic evaluation of equations when contrasted with unfamiliar places ($M = -84$ ms), $t(36) = -3.40$, $p = .002$, $d = -0.57$, but men did not show negative associations to math relative to unfamiliar places ($M = 14$ ms), $t(36) = 0.33$, $p = .74$,

$d = 0.06$. As with the first task, this gender difference in implicit attitude was significant, $F(1, 72) = 6.05$, $p = .02$, $d = 0.58$.[2]

These data increased our confidence that we were reliably detecting a difference that could be elicited with a variety of representations of math and contrasting categories. Together, the serendipitous results from two studies and the results from an additional preliminary study provided the basis for further exploration of group membership, identity, and stereotypes on math preference and performance.

Table 1 presents the main concepts of attitude, identity, stereotyping, and performance as well as the manner in which each is operationalized. In two focal studies, we investigate the relationship among gender group membership, strength of identification with the group, and math attitudes and stereotypes. In addition, we explore the correspondence and unique predictive utility of implicit and explicit components of social cognition. In Study 1, we test the tenet of consistency theories that concepts associated with the self are attitudinally privileged. We examine the strength of implicit math attitudes, the role of gender, and associations between attitude (math + good) and identity (math + me). In Study 2, we examine a more complete set of potential interdependencies of self, social group (gender), and preferences for academic orientation. For women, math + male associations (stereotypes) and me + female associations (gender identity) should relate to more negative identification and attitudes toward math because of the learned dissociation between math and women's social group. For men, the opposite pattern should appear. Strong math + male and me + male associations should be related to more positive identification with and attitudes toward math because of the existing positive association between math and men's social group. We provide a combined analysis section in which data from the preliminary study and the two focal studies are integrated to examine the links between implicit forms of attitudes, identity, and stereotypes and their explicit, self-reported counterparts. Across studies, consistency among implicit attitudes, identity, and stereotypes provides an understanding of the presence and perseverance of gender differences in orientations toward math.

Table 1
Description of the Concepts Examined in This Article

Concept	Description	Measure
Math attitude	Preference for math	Implicit: strength of association between math and pleasant versus math and unpleasant (compared with arts) Explicit: difference in self-reported preference for math (compared with arts)
Math identity	Identification of oneself with math	Implicit: strength of association between self and math versus other and math (compared with arts) Explicit: difference in self-reported identification with math (compared with arts)
Math–gender stereotype	Belief that math is male rather than female	Implicit: strength of association between math and male versus math and female (compared with arts) Explicit: difference in self-reported belief that math is male versus math is female (compared with arts)
Gender identity	Identification of oneself with male or female	Implicit: strength of association between male and self versus female and self (compared with other)
Math performance	Performance on standardized math test	Subscore on the math portion of the SAT (compared with the verbal subscore)

Note. Measures varied slightly throughout the studies where the concept *math* was occasionally replaced with related concepts such as *science* or *equations* and the concept *arts* was occasionally replaced with related concepts such as *language*.

Study 1

On the basis of the findings from three previous studies, we constructed three tasks to measure the strength of implicit attitudes toward math and science. In addition, we examined the association between math and self (i.e., math identity). Cognitive consistency among identity and attitude should emerge because concepts that are more closely associated with the self should also be more positively regarded. Assuming that the gender difference in math attitudes observed in the preliminary study would be replicated, we further expected that men would show stronger implicit identification with math (math + me) than would women. In addition, across all participants, irrespective of gender, variation in math identity should correspond with variation in math attitudes. If corroborated, these findings could serve as the basis of a broader set of predictions regarding social group, attitudes, stereotypes about scholarly endeavors, and academic performance.

Method

Participants

Eighty-three undergraduates at Yale University participated in Study 1 in fulfillment of partial course credit in introductory psychology. Four participants were removed because they made excessive errors on the IATs (> 20%), which left data from 79 undergraduates (40 women, 39 men) for all analyses.

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[2] A third task was included in the preliminary study that measured preferences for single digit strings (e.g., *111*, *222*, *33333*) versus words representing digits (e.g., *one*, *two*, *three*). This task varied the representational form of math rather than the underlying concept. A significant preference for the word form over the digit form of numerical concepts was obtained, $F(1, 72) = 11.09$, $p = .001$, $d = 0.78$, with no accompanying gender difference. That is, when the comparison categories both represented math, men and women did not differ in their evaluations, although both showed stronger negative automatic evaluation of digits than of words. The presence of a gender difference on the other two tasks but not this one suggests that such a difference may only be apparent when the task captures a difference in the underlying meaning of the concepts. A gender difference was not apparent when the categories captured only surface-level differences in representational form. Note that the serendipitous findings where gender differences were observed compared digits (e.g., *1234*) with letters (e.g., *ABCD*) that did not represent mathematical concepts.

Materials

Implicit attitude tasks. Three IATs were used to examine implicit attitudes toward math and science concepts relative to arts and language concepts. The math/language task was identical to that used in the preliminary study, and its main purpose was to provide direct replication. Two additional tasks contrasted math/arts (e.g., *algebra*, *equation* vs. *poetry*, *symphony*) and science/arts (e.g., *physics*, *NASA* vs. *sculpture*, *drama*). Three lists of 10 pleasant (e.g., *love*, *rainbow*, *heaven*) and 10 unpleasant words (e.g., *death*, *torture*, *hatred*) were drawn from published norms (Bellezza, Greenwald, & Banaji, 1986; see the Appendix for a full list of stimuli). The lists of pleasant and unpleasant stimuli were randomly assigned to the three attitude tasks.

Implicit identity task. We constructed a fourth IAT to examine the strength of the association between math/arts and self/other (math/arts identity). The self/other dimension required participants to distinguish between items that represented the self (e.g., *I*, *me*, *mine*, *myself*) and others (e.g., *they*, *them*, *their*, *theirs*). An individual who is highly identified with math relative to arts should more rapidly pair math with self than math with other.

Explicit measures. To assess explicit attitudes toward math and arts, we had participants complete paper-and-pencil questionnaires. Specifically, we used feeling thermometers (preference ratings based on a 0–100 scale from *cold/unfavorable* to *warm/favorable*) to assess participants' feelings of warmth toward math and arts as academic domains. By taking the difference between the math and arts temperature ratings, we made the explicit attitude measures comparable to the implicit measures. Positive values indicate positive explicit attitudes toward math relative to arts; negative values indicate negative explicit attitudes toward math relative to arts.

Participants also completed five semantic differential scales measuring attitudes toward math and arts. Dichotomous pairs of adjectives anchored each end of a 7-point scale (from -3 to 3): *good–bad*, *happy–sad*, *delightful–disgusting*, *beautiful–ugly*, *approach–avoid*, and *unafraid–afraid*. Reasonable consistency among measures ($\alpha = .80$) allowed us to create a composite semantic differential preference score by averaging the adjective pairs. Once again, we created a relative measure by subtracting the average score for math attitude from the average score for arts attitude. In addition, strong correspondence between the temperature and semantic differential composite ($r = .76$) justified combining these two measures of explicit preference, after we standardized each scale, into a single composite score.

A sixth semantic differential item assessed gender stereotypes about math and arts by using male–female as anchor points. The difference between associations of math to male–female and arts to male–female created an index of explicit gender stereotyping of math relative to the arts. Higher values indicate stronger math + male (and arts + female) associations than math + female (and arts + male) associations.[3]

Three items assessed explicit math/arts identity by measuring the subjective link between self and math/arts: (a) "Do you consider yourself to be more mathematical or more artistic?" (b) "I consider myself to be a 'math person,'" and (c) "I consider myself to be an 'arts person.'" To calculate a score of identity with math relative to arts, we combined Item a with the difference score of Items b and c. A final question regarding expectation of using math in one's career was considered separately. An oversight resulted in data from these last four items being collected from only half of the participants in Study 1.

Finally, participants completed a demographic questionnaire that included items such as race, age, year in school, and SAT scores. Self-reported SAT scores were used in the present study as a proxy for actual scores on the basis of Walsh's (1998) finding that self-report of SATs is acceptably accurate ($r = .89$). Taking the difference of participants' SAT math score and SAT verbal score, we created a relative SAT score to match the relative implicit attitude score. The results for explicit measures are set aside for focused discussion in the Combined Analyses section.

Procedure

After reviewing informed consent, participants completed all the implicit measures, followed by the explicit measures. The IATs were performed on a personal computer with a 15-in. monitor using F-IAT software (Farnham, 1997). To perform the IAT, participants placed one finger on the *A* key of the keyboard (the left key), and another finger on the *5* key (the right key) of the keypad. For half of the task, they were instructed to respond by pressing a key (e.g., their left key) each time an item that represented the category *math* (e.g., *algebra*, *equations*) and the category *pleasant* (e.g., *peace*, *love*) appeared in the center of the screen. At the same time, they were asked to press a second key (e.g., the right key) for all items that represented the category *arts* (e.g., *drama*, *poetry*) or words that were unpleasant in meaning (e.g., *hatred*, *bomb*). If participants made an error, an *X* appeared below the item, and they had to correct the error before moving on. For other half of the task, one of the categories was switched such that *math* and *unpleasant* category words were classified on the same key, whereas *arts* and *pleasant* category words were classified on the other key. Each IAT consisted of five practice blocks of 20 trials each plus the two critical blocks, described above, of 40 trials each (a trial consisted of the classification of a single item).

The practice blocks were present to acquaint participants with the appropriate key classification. In the first block, participants discriminated items representing the target concepts (e.g., *math*, *arts*). In the second block, using the same two keys, participants discriminated attribute items (e.g., *pleasant*, *unpleasant*). In the third block, participants practiced categorizing both target and attribute items at the same time such that pairings were created because a target concept and an attribute were required to share an identical response (e.g., math and pleasant items on the left; arts and unpleasant items on the right). Immediately following that practice, an identical block of 40 trials composed the critical data for assessing the association between target concept and attribute. In the fifth block, participants practiced discriminating target concepts again, except that the computer keys representing correct classification were reversed (e.g., arts on the left; math on the right). In the final practice and critical blocks, participants again categorized both concept and attribute items, but with pairings opposite of the previous combined blocks (e.g., arts and pleasant items on the left; math and unpleasant items on the right). Within each block, stimuli appeared in random order, except that in blocks in which both concept and attribute items were presented, trials alternated between presenting target concept and attribute stimuli.

The critical dependent variable was a difference in response latency that we computed by measuring the average speed to respond to math and pleasant items when they were paired together (while unpleasant items were paired with a contrasting category, e.g., language) and the average speed to respond to math and unpleasant items when they were paired together (while pleasant items were paired with a contrasting category).

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[3] This measure of stereotyping differs from that reviewed by Hyde, Fennema, Ryan, et al. (1990). It is somewhat less reactive in that participants were not asked to endorse statements (from *strongly agree* to *strongly disagree*) about women in math (e.g., "When a woman has to solve a math problem, she should ask a man for help"). Rather, participants were simply asked the degree to which math and arts are associated with *male* and *female*. Also, participants' only option to reject the stereotype was to rate both math and arts as equally male and female (whereas slight disagreement to strong disagreement was considered rejection of the stereotype in the scales reviewed by Hyde and colleagues). Therefore, we predicted that participants would be likely to endorse at least some gender stereotyping of math and arts. Indeed, across studies, 45% of women and 80% of men associated math with *male*, and 58% of women and 48% of men associated arts with *female*. Overall, 40% of women and 21% of men were unwilling to associate math or arts with either *male* or *female*.

The difference in average response latency was taken as an implicit assessment of preference (e.g., liking for math relative to the arts).

Counterbalancing of the four IATs was achieved in a Latin-square design. The math/language task, a direct replication of the preliminary study, appeared last for all participants. In addition, the order of category pairings within task was counterbalanced across participants. Demonstration tasks of the IAT procedure similar to that described here can be sampled on the Internet at http://www.yale.edu/implicit.

Results and Discussion

Data Preparation

Data from the first two trials of each block served as buffer items and were eliminated. In keeping with Greenwald et al. (1998), all response latencies falling below 300 ms were recoded as 300 ms, and those over 3,000 ms were recoded as 3,000 ms; 107 of 24,648 (0.43%) trials were thus recoded. The error rate across trials was 5.48% (1,350 of 24,648). Errors were coded but retained in all analyses. To normalize the skewed latency distributions, we transformed latencies by a reciprocal transformation into speed (responses per second; Ratcliff, 1993).[4] All inferential statistics were performed on speed distributions. For ease of interpretation, however, all figures report response latency data in milliseconds. In all cases, women were dummy coded as 1, and men were coded as -1.

We analyzed each measure of automatic evaluation by taking a difference score between performance (i.e., average response latency) when math was paired with unpleasant attributes and performance when math was paired with pleasant attributes. We took positive values to indicate a positive evaluation of math or science relative to the contrasting category.

Implicit Attitude and Identity

We averaged responses for the three implicit attitude assessments to create a single composite measure of implicit evaluation of liking for science/math relative to arts/language. As in the preliminary study, both men and women revealed negative implicit attitudes toward math/science; men: $t(38) = -5.09$, $p = 10^{-5}$, $d = -0.83$; women: $t(39) = -11.95$, $p = 10^{-14}$, $d = -1.91$, but women showed stronger negative evaluations of math/science than men did, $t(77) = 4.24$, $p = 10^{-5}$, $d = 0.97$.

In further analyses, we tested the effects for each task individually (see Figure 1). The math/arts attitude task revealed a strong negative implicit evaluation of math relative to arts. Though both men and women negatively evaluated math (men: $t[38] = -4.94$, $p = 10^{-5}$, $d = -0.80$; women: $t[39] = -12.88$, $p = 10^{-15}$, $d = -2.06$), women's attitudes were significantly more negative, $t(77) = 4.42$, $p = 10^{-5}$, $d = 1.01$. The science/arts attitude task revealed similar results. Although both men and women negatively evaluated science compared with arts (men: $t[38] = -4.72$, $p = 10^{-5}$, $d = -0.77$; women: $t[39] = -12.39$, $p = 10^{-15}$, $d = -1.98$), women had stronger negative evaluations of science than did men, $t(77) = 4.19$, $p = 10^{-5}$, $d = 0.95$. As in the preliminary study, an overall negative evaluation of math relative to language was observed on this task for both groups; men: $t(38) = -3.08$, $p = .004$, $d = -0.50$; women: $t(39) = -5.94$, $p = 10^{-7}$, $d = -0.95$. In addition, a gender difference showing more negativity toward math for women was observed, $t(77) = 2.17$, $p = .03$, $d = 0.49$.

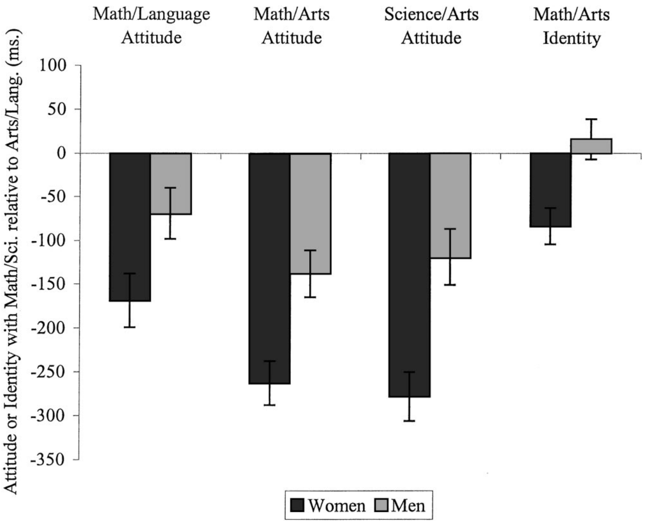

Figure 1. Implicit math attitudes and math identity separated by participant sex. Negative values indicate a negative attitude toward math relative to arts or language, or a weaker identity with math relative to arts (Study 1). Sci. = science; Lang. = language.

The fourth task in Study 1 assessed implicit identification of oneself with math relative to arts, with the expectation that patterns of identification with math would mirror the pattern of evaluation of math. As is evident from the graph for the math/arts identity task in Figure 1, women identified more strongly with arts than with math, $t(39) = -3.90$, $p = .0004$, $d = -0.62$, whereas men did not preferentially identify with arts or math, $t(38) = 0.37$, $p = .71$, $d = 0.06$. That gender difference was statistically reliable, $t(77) = 2.97$, $p = .004$, $d = 0.68$.

Correlations Between Implicit Attitude and Identity

Table 2 presents correlations among the three evaluative measures (math/language, math/arts, science/arts) and shows them to be robustly related to one another. Relationships among these measures, which were designed to capture the same underlying construct, remain high when one looks at men and women separately. Correlations for men ranged from .56 to .61, and correlations for women ranged between .59 and .67. Supporting the idea that attitudes and identity are associated, each of the three implicit math attitude effects showed a significant and positive correlation with math identity. The stronger the implicit liking for math was, the stronger was the implicit identification with math.

Summary

From the preliminary study and Study 1, we learned that negative attitudes toward math are sufficiently internalized to be detected, at least in a North American sample, on measures of

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[4] No significant differences in analyses for any of the three studies resulted from including versus excluding error trials. Results did not significantly vary regardless of whether the data were transformed.

Table 2
Correlations Among Implicit Measures (Study 1)

Measure	Implicit math/arts attitude	Implicit science/arts attitude	Implicit math/lang attitude	Implicit math/arts identity
Implicit science/arts attitude	.66****	—		
Implicit math/lang attitude	.63****	.63****	—	
Implicit math/arts identity	.58****	.42****	.43****	—

Note. Lang = language.
**** $p < .0001$.

implicit evaluation. In addition, both studies show that women, compared with men, had stronger negative evaluations of math.

In many cultures, perhaps especially in the United States, math and related concepts are known to be viewed with disfavor in spite of the powerful thinking tools these concepts offer. An especially negative evaluation may have been detected at Yale, a liberal arts college, where students strongly favor majors in the humanities relative to those in the sciences, especially the physical sciences. Data were collected from visitors to a demonstration Website in which participants have the opportunity to assess implicit biases for a variety of topics (e.g., ethnicity, age, gender), of which math/arts attitude was one (see Nosek, Banaji, & Greenwald, 2002, for more detail). In a sample of about 19,000 participants, we found negative automatic evaluation of math relative to arts ($d = 0.82$), with women ($d = 0.99$) showing stronger negativity toward math than did men, $d = 0.58$, $F(1, 18587) = 539.00$, $p = 10^{-117}$, which both validates the laboratory finding and shows that the obtained effect is not restricted to a sample of liberal arts college students.

Many psychological theories, including cognitive consistency theories, are based on the assumption that individuals generally hold themselves in positive regard. Accordingly, liking for the self extends to liking for attributes associated with the self and the social group. The data from Study 1 conform to these expectations. Participants for whom math was more closely aligned with the self showed more liking for math than did participants for whom math was less aligned with the self, and this relationship persisted within gender groups.

A widespread belief in American culture suggests that group membership should not constrain the choices and preferences of group members. Being a girl need not prevent one from becoming a police officer, senator, or mathematician. Being a boy need not prevent one from becoming a nurse, kindergarten teacher, or primary caregiver. In fact, all programs promoting equal opportunity seek the removal of external constraints for individual pursuits. Yet until the internal, mental constraints that link group identity with preference are removed, the patterns of self-imposed segregation may not change. Study 1 demonstrates the first basic link between group membership (being male or female) and a preference for an attribute associated with the group (math).

Study 2

Knowledge and liking are assumed to be independent constructs. That is, one can know something (e.g., the facts about race and crime or gender and math), but such knowledge, it is assumed, need not be associated with one's preferences. A woman can know that women are less likely to excel in math than are men, but that need not translate into her own attitude toward math—she can consciously choose to have a positive attitude and pursue mathematics as a career. Banaji (2001) made the point that such a distinction is appropriate when one is considering the representation of explicit attitudes and knowledge but not for implicit ones, for which knowing and liking may not be easily distinguished. In this study, we consider whether knowledge, in the form of gender stereotypes about math, relates to liking, in the form of evaluations of math. We first examine the simple relationship of math–gender stereotypes and gender identity with math attitudes and math identity. In addition, we examine more complex interrelationships among attitudes, identity, and stereotypes, with a particular emphasis on the prediction that possession of the same knowledge (stereotype) has opposite relationships with attitudes depending on group membership (gender). Finally, counter to the literature using self-report measures, which has shown widespread rejection of math–gender stereotypes, we investigate whether implicit measures reveal strong math–gender stereotyping in both men and women.

Math–Gender Stereotypes

Stereotypes regarding women in math and science are well known (e.g., women do not like math, men are better at math), and such beliefs are hypothesized predictors of math participation, attitudes, and even performance (Eccles, 1987; Hyde, Fennema, Ryan, et al., 1990; Steele, 1998). Research on the prevalence of this stereotype indicates that both men and women (although men to a lesser extent) reject the view that math should be more strongly associated with men than with women (Hyde, Fennema, Ryan, et al., 1990). Explicit rejection of math–gender stereotypes does not, however, guarantee that these stereotypes are not involved in the interplay of group membership and preference.

Implicit math–gender stereotypes may reveal the role of such knowledge on individual attitude and identity where explicit measures have been less revealing. Because implicit beliefs are not dependent on endorsement, such stereotypes could shape choices by subtly constraining preferences without the individual's awareness or conscious exertion of choice. Consciously expressed preferences for math may be viewed by the individual (and others) to be a function of his or her own choosing (e.g., "I just don't like math") when, in fact, those preferences may be traced to implicit social group identity and implicit knowledge of the attributes associated with the group. It is important to note that the possession of an implicit association that links math with male has exactly opposite predictions depending on whether the possessor is a woman or a man. Specifically, for women, stronger math + male associations should be associated with more negative math attitudes and weaker math identity. On the contrary, for men, stronger math + male associations should be associated with more positive math attitudes and stronger math identity. This prediction underscores the manner in which knowledge and group membership might interact in the prediction of individual preference and identity.

Gender Identity

Thus far, we have considered group membership as a binary variable—a person as either male or female—and derived predictions on the basis of those group memberships. However, for both men and women, identification with the gender group can vary, and such variability can be detected both implicitly and explicitly (Bem, 1974; Lemm & Banaji, 2000). In Study 2, we use the continuous variable of gender identity to test whether the strength of identity relates to increases in the bonds between the self and attributes associated with the group. For those who strongly identify as male, group identity should strengthen identification with math as a discipline (i.e., self–math association). Conversely, for those who have a strong identity as female, this identity should weaken the identification with math because female and math are dissociated. Although the strength of gender identity need not fall perfectly in line with gender, those who have a strong male identity are likely to be men, and those who have a strong female identity are likely to be women (Lemm & Banaji, 2000). The consequences for social cognition are obvious; women who are more strongly identified with their gender (female) ought to show more negative math attitudes and weaker math identity than should women who are more weakly identified with female. Conversely, men who are more strongly identified with their gender (male) ought to show more positive math attitudes and stronger math identity than should men who are more weakly identified with male.

Method

Participants

Ninety-seven introductory psychology students at Yale University participated in partial fulfillment of course requirements. Six participants were removed from the analysis for excessive errors on the IATs ($> 20\%$) or for not following instructions, leaving 91 participants (46 female, 45 male) in the analysis.

Materials

Implicit measures. Participants completed four tasks to measure implicit social cognition. Two of the tasks, math/arts attitude and math/arts identity, were identical to those used in Study 1. We created a new task to measure the strength of association between academic domain (math/arts) and gender (male/female), to provide a measure of the math–gender stereotype. A strong math–gender stereotype is evident if responses are faster with math + male pairings (along with arts + female) as opposed to math + female pairings (along with arts + male). We created a second new task to measure the association between self (*I*/*they*) and gender (male/female), to provide a measure of gender identity. Gender groups were represented with stimuli that were denotative of gender categories (e.g., *male*, *boy*, *female*, *girl*). A male gender identity would be evident if responding was faster in male + self pairings compared with female + self pairings; a female gender identity would be evident if the opposite were true. A list of stimuli for all four IATs in Study 2 can be found in the Appendix.

Explicit measures. Explicit measures (including self-reported SAT performance) administered in Study 2 were identical to the items administered in Study 1. Results for these measures were consistent across studies, and discussion of them is largely deferred to the Combined Analyses section.

Procedure

The procedure was identical to that used in Study 1. Presentation of implicit measures was counterbalanced in a Latin-square design.

Results and Discussion

Data Preparation

Consistent with the standards for handling such data, outlier trials were first computed and recoded. Only 0.33% (89 of 28,392) of the trials were outside the 300–3,000 ms range and were recoded as 300 ms or 3,000 ms. In addition, 5.41% (1,537 of 28,392) of the trials were coded as error responses but retained. Following standard practice, we centered variables included in regressions to allow proper interpretation of the beta weights for interaction effects.

Implicit Measures

Implicit math attitudes and math identity. As in Study 1, we included measures of math attitudes and math identity, and they replicated the results from that study. Both men and women evaluated math more negatively than arts; men: $t(44) = -5.97$, $p = 10^{-7}$, $d = -0.90$; women: $t(45) = -11.60$, $p = 10^{-15}$, $d = -1.73$ (see Figure 2). Women showed more negative evaluation of math than men did, $t(89) = 4.26$, $p = 10^{-5}$, $d = 0.90$. Also replicating Study 1, for math identity, women showed stronger identification with arts relative to math than men did, $t(89) = -2.76$, $p = .007$, $d = -0.59$.

Implicit math–gender stereotypes. Implicit math–gender stereotypes, newly introduced in Study 2, assessed the strength of association between math/arts and male/female. Both men and women classified math + male (and arts + female) more easily than the opposite pairings, $F(1, 89) = 192.70$, $p = 10^{-24}$, $d = 1.47$ (see Figure 2). No gender difference in the magnitude of this effect was obtained; both men and women showed implicit math–gender stereotypes equally, $t(89) = 0.41$, $p = .68$. In other words, although men and women differed in their preference for math, they showed identical implicit knowledge relating gender and math.

This similarity on the strength of stereotype becomes important as we see that, from an equally strong math–gender stereotype, a different profile of preferences and performance can arise. In particular, women who hold strong math + male stereotypes ought to like or identify with math less than should women who hold weaker math + male stereotypes. However, men who hold strong math + male stereotypes ought to like and identify with math more than should men who hold weaker math + male stereotypes. We tested these hypotheses by submitting participant gender (coded −1 for men, 1 for women), math–gender stereotypes, and the interaction between participant gender and stereotyping to three hierarchical regressions predicting attitudes, identity, and performance as well as follow-up correlational tests separately for men and women.

Table 3 presents two-step hierarchical regressions in which participant sex and math–gender stereotypes were entered in the first step to test their simple effects on the dependent variable, followed by the interaction between sex and math–gender stereotypes to test for moderation. In Step 1 of the model predicting math attitudes, the sex difference in attitude described in the previous section was observed. Women evaluated math more negatively than did men. When the interaction between sex and stereotype was entered in Step 2, a significant negative interaction was observed. That is, stronger math + male stereotypes were associated with more positive math attitudes for men than for women.

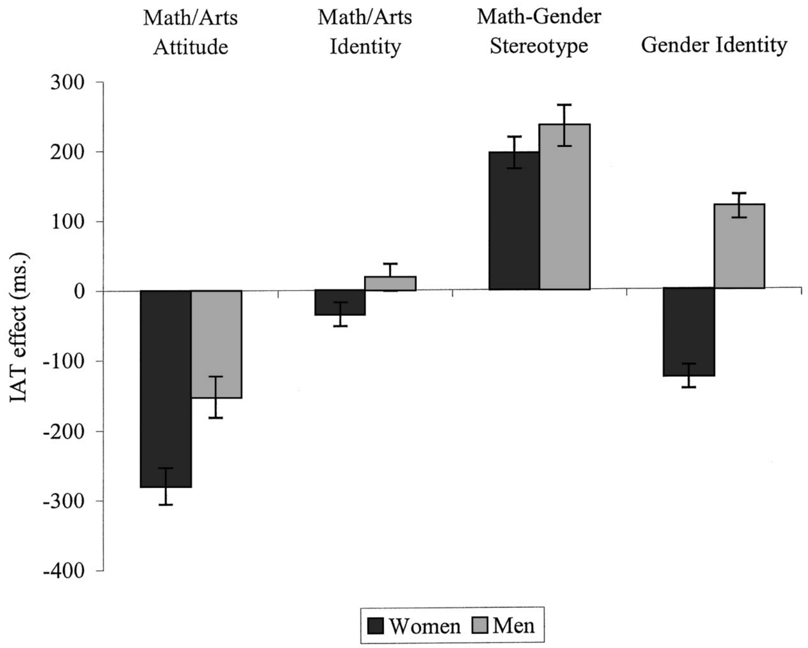

Figure 2. Implicit math attitudes, math identity, math–gender stereotypes, and gender identity separated by participant sex. For the math attitude task, negative values indicate negative attitudes toward math relative to arts. For the math identity task, negative values indicate weaker identity with math relative to arts. For the math–gender stereotype task, positive values indicate stronger *math* + *male* (and *arts* + *female*) associations than *math* + *female* (and *arts* + *male*) associations. For the gender identity task, positive values indicate a link between *me* and *male*, and negative values indicate a link between *me* and *female* (Study 2). IAT = Implicit Association Test.

Further, an examination of the relationship between stereotype and attitude for men and women independently showed a positive relationship for men ($r = .35$, $p = .02$) and a negative relationship for women ($r = -.34$, $p = .02$). A similar, though weaker, pattern was observed when math identity was the dependent variable instead of math attitudes. Stronger math + male stereotypes were associated with stronger math identity for men ($r = .24$, $p = .12$) and weaker math identity for women ($r = -.28$, $p = .06$).

In this sample, there was no gender difference in relative SAT performance. Even so, the Gender × Stereotype interaction was a significant negative predictor of SAT performance. A stronger math + male stereotype was associated with better performance for men ($r = .51$, $p = .0007$) but somewhat worse math performance for women ($r = -.16$, $p = .30$).[5]

To summarize, men and women held equally strong implicit stereotypes linking math to male and reported comparable SAT scores. Despite the lack of gender differences in mean levels of math–gender stereotypes and SAT performance, variability in stereotyping was differentially related to attitudes, identity, and performance between groups. For women, the larger the magnitude of the math + male stereotype association was, the weaker was their liking for math, the lower was their identification with math, and the worse was their performance on math SATs. For men, the opposite effect was obtained; the math–gender stereotype related to a more positive math attitude, stronger math identity, and better math performance. The nexus of implicit associations among stereotype, attitude, and identity reveals the consistency or balance within such systems and reveals how preferences for a domain might be shaped by group membership.

Implicit gender identity. Although most individuals recognize themselves to be members of one gender or the other (a dichotomous classification), the degree to which one is identified with the social group *male* or *female* can vary. In this section, we tested the effects of social group membership and identity with one's group on math attitudes, math–gender stereotypes, and math identity. First, we assessed associations between self and group (gender identity). As expected, women showed strong identification with female relative to male, $t(45) = -7.63$, $p = 10^{-9}$, $d = -1.14$, and men showed a strong identification with male relative to female, $t(44) = 8.01$, $p = 10^{-10}$, $d = 1.21$ (Figure 2). These are strong effects, and they reflect a truism about gender—men largely identify with being male; women largely identify with being female.

The moderational analyses described in the previous section were replicated using gender identity instead of participant gender as a predictor, and it is not surprising that those results were very similar (see Table 3). Using gender identity produced results that were functionally identical to those observed above using the

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[5] Similar effects are observed when the SAT math subscore is used as the dependent variable rather than the relative SAT performance score. For men, stronger implicit math + male associations were positively related to SAT math scores ($r = .42$, $p = .006$), whereas a slight, nonsignificant negative relationship was observed for women ($r = -.06$, $p = .70$).

Table 3
Beta Weights From Hierarchical Regressions Predicting Implicit Math/Arts Attitude and Identity and SAT Performance

	Sex and math–gender stereotypes				Gender identity and math–gender stereotypes			
		Step 1		Step 2		Step 1		Step 2
Dependent variable	Adj. R^2	Sex	Stereotype	Sex × Stereotype	Adj. R^2	Gender identity	Stereotype	Gender Identity × Stereotype
Implicit math/arts attitude	.24	−.41****	−.02	−.32***	.21	−.39***	.03	−.30**
Implicit math/arts identity	.11	−.28**	−.04	−.25*	.21	−.45****	.03	−.19*
Relative SAT performance	.11	−.14	.13	−.32**	.04	−.06	.13	−.25*

* $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

dichotomous participant gender. The advantage of including gender identity is that it allows examination of whether the degree of association between self and gender group related to math attitudes and math identity. For women, stronger female gender identity was associated with more negative math attitudes ($r = -.32$, $p = .03$) and weaker math identity ($r = -.40$, $p = .006$). For men, stronger male gender identity was associated with stronger math identity ($r = .33$, $p = .03$) but was not associated with math attitudes ($r = -.12$, $p = .43$).

Summary

In Study 2, we found additional evidence that group membership predicts personal preferences and identification with math. Implicit math–gender stereotypes were prevalent and equally strong among men and women. Yet variation in the magnitude of that stereotype differentially predicted attitude, identity, and performance. Expectations for one's group, in the form of math–gender stereotypes, were related to individual liking and identification with math as well as performance. Further, the strength of female gender identity was associated with increased negativity and weaker identification with math. The negative relationship between a group (e.g., women) and a domain (e.g., math) may have the result that those who identify strongly with the group are themselves less likely to orient toward the domain.

Data from this study are correlational and do not distinguish among the causal priority of attitudes, identity, and stereotypes. Indeed, we believe that the relationships are likely to be multidirectional, although through our analysis strategy we do emphasize one direction that is consistent with previous research. That is, stereotypes are present in the environment before an individual forms a personal attitude toward math, and here we regard them to have a causal advantage in driving attitude and performance. In support, we note that the average R^2 for the models that we tested was .15 (15% of variance explained), whereas models testing the reverse causal pattern explained about half ($R^2 = .07$) of the available variance. Clearer evidence for the causal relationships among these variables is left for future research.

Combined Analyses: Implicit–Explicit Correspondence, Relation With Performance, and Effects of Major

In this final section, we pay special attention to the relationship between implicit measures of attitudes, identity, and stereotypes and their explicit, self-reported counterparts. Theory and research on implicit social cognition has emphasized the independence of these two modes of thought and evaluation (Greenwald & Banaji, 1995). Social cognition about math is of particular interest in investigations of distinctions between implicit and explicit social cognition because, for the most part, people are not motivated to conceal their personal preferences. Therefore, one of the primary factors assumed to distinguish implicit and explicit measurement, self-presentation, is not very relevant to the expression of math preferences. People generally express negativity toward math without compunction. Further, these data afford an opportunity to test whether implicit and explicit attitudes have unique predictive power, even when they are known to correspond with each other. Finally, we examined whether another social factor (college major) moderated gender differences in implicit math attitudes. For most of the analyses in this section, we combine data across studies to answer questions that were not addressed in any single previous study because of lack of power.

Relations Between Implicit and Explicit Attitudes

A central theme in research on unconscious processes is the relationship between such measures and relatively more conscious measures (Banaji, Lemm, & Carpenter, 2001; Blair, 2001; Brauer, Wasal, & Niedenthal, 2000; Greenwald & Banaji, 1995). Early evidence suggested that these two processes might proceed independently of one another and thus were not related (Banaji & Greenwald, 1994; Banaji & Hardin, 1996). Yet recent evidence has shown that such relationships can vary from weak to strong (see Nosek et al., 2002), and others have shown that, under some conditions, measures of explicit and implicit cognition are reliably and positively associated (Cunningham, Preacher, & Banaji, 2001; Lepore & Brown, 1997; Lemm & Banaji, 2000; Nosek et al., 2002; Perdue & Gurtman, 1990). Explicit attitudes toward math are not likely to be as subject to social desirability concerns as are attitudes toward particular social groups (e.g., the elderly, the poor, African Americans). Also, the college students we tested ought to be well practiced at knowing and expressing attitudes toward academic orientations. For these reasons, we expected that implicit and explicit attitudes would be positively related. Yet there is growing evidence to suggest that explicit and implicit measures can be positively and significantly correlated while remaining separate factors (Cunningham et al., 2001; Greenwald & Farnham, 2000). If so, their unique contributions ought to be observed in their associations with other variables.

Relating Implicit Attitudes and Performance

Research on math attitudes has consistently shown a positive relationship between explicit attitudes and performance (Hyde, Fennema, & Lamon, 1990). This is not a surprising finding; one's explicit math attitudes and knowledge of one's performance on math tests are both available to conscious awareness and are likely to shape each other. On the other hand, implicit attitudes are relatively inaccessible to deliberative processes or conscious control. A demonstration of relationships between implicit math attitudes and math performance (as assessed by the SAT) would provide new evidence for the predictive power of implicit attitudes.

Does Undergraduate Major Moderate Gender Differences?

Gender differences in implicit math attitudes may be partially a function of gender differences in participation. Men are much more likely to pursue mathematically related majors and careers. It is possible that men and women who have selected math-related majors will show similar implicit math attitudes. A more intriguing possibility is that gender differences in implicit math attitudes will persist even when we control for undergraduate major. This is of particular relevance for women who have selected math-intensive majors, because this group suffers high rates of attrition (NSF, 1996) and because these women's behavioral choice marks them as defiant of math–gender stereotypes in the culture. We hypothesized that students pursuing math-intensive majors would show more positive implicit math attitudes than would students pursuing other majors. More important, we examined whether gender differences in math attitudes would persist after we controlled for undergraduate major.

Results and Discussion

Data Preparation

Initial preparation of the data proceeded as in the three individual studies. The implicit measures for each study were standardized to have a mean of 0 and a standard deviation of 1 to allow the magnitude of their effects to be directly comparable. Explicit attitudes were standardized in a similar form for comparative analysis.

Relationships Among Implicit Measures, Explicit Measures, and Performance

Correspondence among implicit and explicit math attitudes, math identity, and gender identity. Whereas theory and research have emphasized the dissociations between implicit and explicit social cognition, a growing body of research is providing evidence of conditions in which implicit and explicit preferences do relate. Implicit and explicit relationships across studies are summarized in Table 4. More positive implicit math attitudes and identity corresponded with more positive explicit math attitudes and identity. Far from being unrelated, these measures showed robust relationships, indicating that implicit–explicit correspondence should be reliably observed for some attitude objects.

Implicit–explicit correspondence was not limited to relationships within a single construct (e.g., attitudes). Implicit gender identity was related to explicit math attitudes and explicit math identity. A stronger implicit identification with male (as opposed to female) was associated with more positive explicit math attitudes and a stronger explicit math identity. This effect is consistent with a central assumption of cognitive–affective consistency theory—the stronger the association is between self and group (gender identity), the greater the extent to which individual preferences (attitudes) mirror the expectations of the group (stereotypes), even when those preferences appear to be freely chosen.

Table 4
Correlations Between Implicit and Explicit Measures (Combined Analyses)

	Explicit math/arts attitude		Explicit math/arts identity		Explicit math–gender stereotype	
Measure	*r*	*n*	*r*	*n*	*r*	*n*
Implicit math/arts attitude	.42****	243	.48****	132	.05	243
Implicit math/arts identity	.38****	169	.40****	132	.07	169
Implicit gender identity	.38***	91	.38***	88	.17	91

*** $p < .001$. **** $p < .0001$.

Implicit and explicit stereotypes: Their relationship with attitudes, identity, and performance. Many theories of math participation and achievement are premised on the assumption that gender stereotypes play an important role in shaping math attitudes, identity, and performance (Eccles, 1987; Hyde, Fennema, Ryan, et al., 1990; Steele, 1998). However, the reluctance of participants to explicitly endorse math–gender stereotypes has made it difficult to adequately test these theories. Previously, we showed that men and women hold equally strong implicit math–gender stereotypes. In this section, we examine the variability in stereotyping by directly comparing the predictive power of implicit versus explicit stereotypes on the math attitudes and identity. Because they reside outside of conscious control, implicit stereotypes may predict explicit preferences even when explicit stereotypes fail to predict such preferences.

To test whether implicit and explicit stereotypes were predictive of attitudes and identity, we submitted measures of implicit and explicit math–gender stereotyping assessed in Study 2 as well as participant sex to five independent hierarchical regressions. We tested models predicting (a) implicit math attitudes, (b) implicit math identity, (c) explicit math attitudes, (d) explicit math identity, and (e) relative SAT performance. Evidence from Experiment 2, in which we investigated implicit measures only, showed that math–gender stereotypes had opposite consequences for men versus women. Specifically, we found that stronger math + male associations were related to stronger math orientations for men but to weaker math orientations for women. The present analysis shares the prediction that stereotypes should have opposite consequences for men and women. Therefore, the principle predictors of interest were the interactions of participant sex and stereotyping. The interactions test whether explicit and implicit stereotypes have opposing relationships to math attitudes, identity and performance for men and women.

Table 5 presents the beta weights for five predictors that were entered into each of the four hierarchical regressions. To give explicit measures the greatest opportunity to predict the dependent variables, we entered explicit stereotypes, participant sex, and the Explicit Stereotype × Sex interaction in Step 1. The implicit stereotype and Implicit Stereotype × Sex interaction (predictors) were entered in Step 2. Negative beta weights for the two interactions would indicate that stronger math + male associations were related to more positive attitudes or identity for men compared with women, consistent with our prediction.

Results indicate that the Explicit Stereotypes × Participant Sex interaction did not predict any of the five dependent variables (implicit or explicit). However, the Implicit Stereotypes × Participant Sex interaction showed consistent and robust predictions for both implicit and explicit math attitudes and identity as well as SAT performance. Further, for men, implicit stereotypes were positively related to all five dependent variables—implicit math attitude, implicit math identity, explicit math attitude, explicit math identity, and SAT performance (average $r = .50$). For women, implicit stereotypes were negatively related to all five dependent variables (average $r = -.25$). Despite the fact that explicit stereotypes have no predictive potential for explicit math attitudes, math identity, or math performance, implicit stereotypes were predictive of all three. Further, for men, stronger implicit stereotypes corresponded with stronger math attitudes, identity, and performance. However, for women, stronger implicit stereotypes corresponded with weaker math attitudes, identity, and performance.

These results suggest an intriguing interaction between processes operating outside of conscious control and conscious experience. To understand why implicit stereotypes demonstrate significantly more predictive power than do explicit stereotypes, we consider how personal standards or ideals might obfuscate the relationship between gender stereotypes and math attitudes and identity. Whereas explicit stereotypes are likely to be heavily influenced by personal standards (i.e., the desire not to stereotype groups), it appears that implicit stereotypes are not subject to the same influences. Consequently, a stereotype may be maintained outside conscious awareness although it is neither wanted nor endorsed consciously, yet still influence both consciously and unconsciously held attitudes.[6]

Implicit and explicit attitudes and identity: Their relationship with performance. The relationship between explicit math preferences and math performance is well documented. As expected, SAT performance was positively related to explicit attitudes ($r = .49$, $n = 227$, $p < .0001$), replicating Hyde, Fennema, and Lamon’s (1990) meta-analysis. The nature of the relationship between explicit attitudes and performance is not difficult to imagine. Explicit attitudes can influence subsequent performance, and one can observe one’s performance and adjust one’s explicit attitudes accordingly. No evidence yet exists to suggest a relationship between implicit math preferences and consequential outcomes such as SAT performance.

A relationship between performance and implicit attitudes is of interest because such a relationship, if it were obtained, could be regarded as more impressive: Implicit attitudes are not subject to conscious consideration or control and presumably cannot consciously influence performance. Results show that SAT performance was positively correlated with implicit attitudes ($r = .38$, $n = 227$, $p = .002$).[7] This finding suggests that implicit attitudes and identity are related to performance measures and provides suggestive evidence of the predictive validity of implicit measures. A follow-up simultaneous regression in which implicit and explicit attitudes were submitted as predictors of performance showed that, even after we removed shared variance, both implicit ($B = 18.12$, $SE\ B = 5.47$, $\beta = .21$, $p = .001$) and explicit attitudes ($B = 33.58$, $SE\ B = 5.34$, $\beta = .40$, $p < .0001$) were significant predictors of performance. That is, implicit and explicit attitudes are not redundant measures of preference. Each carries its own predictive power.

Implicit Math Attitudes by Gender and Major

We report a multiple regression analysis predicting implicit attitude by two grouping variables—gender and undergraduate major (math or nonmath). Undergraduate majors were divided into two groups that delineated majors by emphasis on math in the curriculum. Math, statistics, math-intensive sciences (e.g., physics and chemistry), and engineering were classified as math majors (men, $n = 43$; women, $n = 26$), whereas majors in the humanities and social sciences were classified as nonmath majors (men, $n = 78$; women, $n = 97$).

We performed a simultaneous regression analysis to examine the predictive power of gender and major on implicit math attitudes. The omnibus model was significant, $F(3, 240) = 15.03$, $p < .0001$, $R^2 = .16$, and both grouping variables were significant predictors of math attitudes. Women ($M = -0.36$) showed more negative math attitudes than did men ($M = 0.36$; $B = -0.08$, $SE\ B = 0.02$, $\beta = -.33$, $p < .0001$), and nonmath majors ($M = -0.26$) showed more negative math attitudes than did math majors ($M = 0.67$; $B = -0.05$, $SE\ B = 0.02$, $\beta = -.17$, $p = .005$). There was no interaction between gender and major ($p = .91$).[8]

We found that gender differences in math attitudes persist even among people pursuing math-related degrees. Women in math-

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[6] Readers may note that the beta weights for the Implicit Stereotypes × Participant Sex effect predicting explicit attitudes and identity are larger than those predicting implicit attitudes and identity. This difference may be the consequence of an artifact where implicit measures using reaction time as a dependent variable tend to be less reliable than do explicit measures, hence underestimating the strength of their relationships (Cunningham et al., 2001). As such, we hesitate to interpret this difference until it is replicated in research controlling for differences in reliability.

[7] Explicit-performance correlations exceed corresponding implicit-performance correlations. As mentioned previously, greater unreliability of implicit measures results in underestimation of their specific correlations to a greater extent than is typically observed with explicit measures (Cunningham et al., 2001).

[8] Visually, the standardized means imply that the impact of major is much larger than the impact of gender on implicit attitudes. However, the large difference in sample size between math ($n = 69$) and nonmath majors ($n = 175$) makes the standardized mean difference in major appear larger than the standardized mean difference in gender. Restandardizing these data but retaining the rational zero point (i.e., 0 indicates no relative preference for math or arts/language rather than the group mean) reveals that, if anything, the impact of gender on implicit attitudes (men, $M = -0.14$; women, $M = -0.31$) is larger than the impact of major on implicit attitudes (math, $M = -0.14$; nonmath, $M = -0.26$). A similar analysis using math identity as the dependent variable rather than math attitudes showed that both major and gender also contribute to differences in implicit math identity. Finally, a group difference in implicit math attitude was observed when we compared the Asian and White participants; Asian Americans showed stronger implicit liking for math than did White Americans.

Table 5
Beta Weights From Simultaneous Multiple Regressions (Combined Analyses)

		Step 1			Step 2	
Dependent variable	Adj. R^2	Sex	Explicit stereotype	Sex × Explicit Stereotype	Implicit stereotype	Sex × Implicit Stereotype
Implicit math/arts attitude	.26	−.42***	.12	−.06	.00	−.32**
Implicit math/arts identity	.11	−.29**	−.00	−.06	.01	−.28*
Explicit math/arts attitude	.36	−.36***	−.02	.18	.29**	−.44****
Explicit math/arts identity	.42	−.33**	.04	−.15	.27**	−.54****
Relative SAT performance	.12	−.07	.24*	−.02	.14	−.31**

* $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

intensive majors ($M = -0.03$) held more negative implicit math attitudes than did men in math-intensive majors ($M = 0.60$), $t(67) = -2.97$, $p = .004$, $d = 0.73$, showing that despite selecting a math-intensive program, women held more negative implicit attitudes than did their male peers. A similar gender difference comparing explicit attitudes of female ($M = 0.43$) and male math majors was also significant ($M = 0.81$), $t(66) = -2.05$, $p = .04$, $d = 0.50$, although the difference on the self-reported measure was somewhat weaker. Choice of major is not sufficient to remove the powerful impact of gender group membership on math attitudes.

General Discussion

Group Membership and Orientations Toward Math

In these studies, both men and women showed strong identification with their own gender group and equally strong gender–math stereotypes. Both groups also showed negativity toward math. Yet a consistent gender difference in implicit attitudes toward and identification with math was consistently obtained. Men showed less negative attitudes and stronger identification with mathematical and science concepts than did women.

Although correlational, the effects are consistent with theories of the role of group membership in influencing choices and preferences. Here we observed them in a variety of ways, both simple and complex. Simple gender differences in implicit math attitudes and math identity were bolstered by other observations. When the attitude task used a contrasting category of unfamiliar geographic locations in the preliminary study, women continued to show relative negativity toward math, whereas men's otherwise negative evaluation turned more positive, demonstrating the relative strength of women's negative attitude. Further, a gender difference in math attitudes was even observed among men and women who had selected a math-intensive major, at least when measured indirectly.

A unique feature of this research is its emphasis on the relative comparison of math with a contrasting domain, predominately arts but also language and unfamiliar places. We believe that within-individual comparisons like these are likely to illuminate personal decisions such as which major to pursue among a cluster of liked or disliked options. We stress the use of various alternative categories against which an attitude is measured, both explicitly and implicitly, because when one speaks of any attitude, the question of "as compared with what?" is present for all modes of measurement. Even so, future research should examine orientations toward math both in relative comparison with other domains and in isolation (the latter to examine the default meaning and attitude toward the concept). Recent methodological developments allow investigations that do not require comparison with a contrasting category (see Nosek & Banaji, 2001, for a description of the go/no-go association task). For now, we leave it to future research to identify the value of these alternative approaches to measuring preference in a variety of domains.

Cognitive–Affective Consistency Among Attitudes, Identity, and Stereotypes

The data from Studies 1 and 2 provide evidence for a host of relationships among components of implicit social cognition. Group membership invites the implicit application of expectations of the group (stereotypes) to the preferences of individuals. Identification with groups, it seems, naturally opens the individual so identified to the options and choices available to the group. It also leaves individuals vulnerable when options and choices are not available to the group. In the studies described here, membership in the category *female* was robustly related to orientations toward math relative to arts (as well as language and unfamiliar places). Women liked and identified with math less than men did. Not only did group membership predict liking for math, the strength of group identity also did—irrespective of actual group membership, the stronger a participant's association was to the group *female*, the less was the preference for math; the stronger a participant's association was with the group *male*, the stronger was the preference for math. In addition, stronger math–gender stereotypes related to stronger math orientations for men but weaker math orientations for women.

Implicit attitudes toward math do not sit in isolation. Attitudes, beliefs, and identity form a rich network of thoughts and feelings that frame one's orientation toward the domain. Greenwald et al.'s (2002) integrative account of implicit social cognition begins with the prediction that concepts that are automatically associated with the self ought to be liked more than should concepts that are less associated with the self. In line with this expectation, math attitudes and math identity were positively related. The more participants identified with math (i.e., showed strong math + me associations), the more they showed positive attitudes toward it. Also in line with consistency theories, women's implicit beliefs that math = male corresponded with reduced math identity and more negative attitudes toward math. Finally, identifying with female (a category not related to math) corresponded with reduced math identity and more negative math attitudes. The unconscious manner in which affective and cognitive attachments to the group are formed and group attributes are implicitly applied to the individual produces a most interesting outcome—the belief that one's preference is one's own. Although a great deal of research has been conducted on the math–gender problem with a focus on attitudes and stereotypes (e.g., Hyde, Fennema, Ryan, et al., 1990), these first studies show the contribution of including less conscious, more automatic modes of thinking and feeling and the opportunity these elements open for future investigation.

We relied on consistency theories for the notion that when imbalance is introduced into a system, it reverts toward maintenance of overall balance. We applied this simple idea to show how group membership and identity serve to maintain inequality in the desire for particular resources of academic orientation. In the face of gender stereotypes about math, striving for balance works against women's development of positive math attitudes and identity with math. For a woman to develop positive attitudes toward math, she must disrupt the balance in the pattern of relationships between math, gender, and self. In particular, a quality that is attached to another "not-me" group needs to become associated to self. This cannot happen unless the mental connections between math and male (stereotype) and/or self and female (identity) are diminished. As seen in the data from these studies, that stereotype is strong and can persist outside conscious awareness or control.

Implicit Stereotypes as the Locus for Influence of Stereotypes on Attitude and Identity

Factors such as cultural beliefs and stereotypes are frequently implicated as predictive of women's orientations toward math. At the same time, women consciously reject the gender stereotypes that exclude women from math (Hyde, Fennema, Ryan, et al., 1990). With women rejecting the validity of the stereotype, it has not been clear how these cultural beliefs nevertheless come to have impact on women's personal preferences for math.

We propose that implicit stereotypes may provide a missing link between the explicit cultural stereotype and its effect on the attitudes and identities of the targets of that stereotype. We observed that, despite the lack of predictive power of explicit math–gender stereotypes, implicit math–gender stereotypes were predictive of math attitudes and identity, measured both implicitly and explicitly. Future investigations of the causal role of stereotypes for developing attitudes and identity can help to determine how cultural stereotypes can influence women's preferences despite widespread explicit rejection of the stereotypes themselves. Women (and men) need not endorse gender stereotypes consciously for these stereotypes to have a mental existence and to influence behavior. The human ability to explicitly reject beliefs that are not considered just or fair may then provide false assurance that stereotypes do not play a role in the formation of preferences that are thought to be of one's independent choosing (i.e., not a reflection of one's group membership). Knowledge of stereotypes, even implicit knowledge, may be sufficient to perpetuate stereotypes and even discourage women's subsequent participation and performance in math domains.

Implicit Social Cognition Is Related to and Distinct From Explicit Social Cognition

Early formulations of the relationship between implicit and explicit social cognition focused on the independence of implicit and explicit preferences, noting the dissociations between the two (Bosson, Swann, & Pennebaker, 2000; Fazio, Jackson, Dunton, & Williams, 1995; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Greenwald & Banaji, 1995). However, the studies in this article show that implicit measures are related to explicit preferences and performance. Other research findings concur with these, showing that explicit and implicit attitudes are more interrelated than was previously thought (Cunningham, Nezlek, & Banaji, 2000; Cunningham et al., 2001). Such research also shows that the relationship between these two families of measures does not mean that they are fully overlapping. In fact, in a test of this issue, Cunningham et al. (2000) showed that a single-factor solution did not fit the data—implicit and explicit attitudes are related but independent. The unique predictive qualities of implicit measures are clearly evident in the studies reported here. In the combined analyses, we noted that both implicit attitudes were related to math performance even after we removed variance shared with explicit attitudes. Likewise, implicit math–gender stereotypes predicted math attitudes and identity where explicit math–gender stereotypes did not. The presence of implicit–explicit correspondence and their unique predictive powers opens an avenue for a new conceptualization of the role of attitudes and beliefs in math performance and participation. Introspective accounts are not the only tools available to investigate math attitudes, identity, and stereotypes.

Conclusion

The data from these studies speak to a central question in social psychology: Do membership in a group and psychological ties to the group shape individual preferences and performance? These studies show that membership in the groups *female* and *male* and strength of identity with these groups are related to math preferences, math identity, and math–gender stereotypes. These tests are correlational and hence necessarily restricted in their ability to allow causal inferences. On the other hand, liking for math and science does not produce assignment to the groups *male* or *female*. Rather, it is assignment to such groups that drives preferences and performance. Liking for math may just as easily reduce gender identification with female as strong identification with female may reduce liking for math. Similarly, with group stereotypes, the strength of the belief that math = male may drive down women's attitudes toward math just as easily as negative attitudes toward math may increase the strength of math–gender stereotypes. For now, we can suggest that a fundamental categorization at birth into the groups *male* or *female* produces identification with one's social group and that such identification shapes and is shaped by experiences that are expected of that social group. From such experiences flow preferences and performance that can be enhancing or limiting insofar as they interfere with free access to modes of thinking and choices that make for a fulfilling and productive life.

The data from these studies indirectly speak to lay views about group differences in preferences and abilities. A not uncommon view, stated clearly by computer scientist David Gelernter (1999), is that gender differences in science participation are not a product of gender bias. Rather, "the real explanation is obvious: women are less drawn to science and engineering than men are" (p. 11). Gelernter reinforced this point by arguing that it is unmistakable that women are not being kept out of science by force so that "they must be *choosing* not to enter, presumably because they don't *want* to; presumably because (by and large) they don't like these fields or (on average) don't tend to excel in them, which is nearly the same thing" (p. 12).

Gelernter's (1999) view is not dissimilar from other expressions about the real wants and choices of other social groups. Butlers, it was assumed, did not wish to be masters, just as women, it was assumed, had chosen to work only in the home. Reminiscent as Gelernter's opinion is of assessments that support one or another form of social domination (e.g., that Asian Indians preferred British rule, that African Americans wished to remain slaves), it is, after all, an opinion and not evidence. It therefore stands in contrast to the evidence from research: that social learning, within the latitude offered by social group membership, can enhance or diminish preferences and desires. Views such as Gelertner's specifically stand in contrast to the evidence presented in this article: that social learning, measured in the form of implicit math–gender stereotypes, are robustly related to want and choice (undergraduate major) and liking (attitude). Therefore, we are led by such facts to conclude that want, and choice, and like are not independent of social learning and that social learning is constrained by the demands of social group identity and group stereotypes. The optimistic view offered by Elizabeth Cady Stanton's descendent that anything is possible for anyone should indeed remain the ideal for equality. But it cannot cloud recognition of the blunt reality that not everything is equally possible for everyone. Societies that aspire to purer forms of democracy need be aware that wanting and choosing can be firmly shaped by membership in social groups.

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Appendix

Category Labels and Stimuli for the Implicit Association Tests

Pleasant/Unpleasant (List 1)
Pleasant: assertive, athletic, strong, compassion, support, sympathetic, laughter, champion, paradise, vacation
Unpleasant: brutal, destroy, ruthless, confusion, insecure, naive, bad, poor, waste, crude

Pleasant/Unpleasant (List 2)
Pleasant: ambition, cuddle, excitement, glory, joy, love, paradise, pleasure, romantic, miracle
Unpleasant: agony, death, detest, disaster, humiliate, jealousy, punishment, stress, tragedy, war

Pleasant/Unpleasant (List 3)
Pleasant: affectionate, cozy, enjoyment, friend, hug, laughter, passion, peace, snuggle, triumph
Unpleasant: afraid, crucify, despise, failure, hatred, irritate, nightmare, slap, terrible, violent

Mathematics/Language (preliminary study and Study 1)
Mathematics: algebra, formula, geometry, equation, subtract, variable, add, square, multiply, numbers
Language: English, grammar, words, sentence, adjective, poetry, verbs, pronoun, paragraph, letters

Equations/Places (preliminary study)
Equations: $5 = 9 - 4$, $7 \times 1 = 7$, $24/3 = 8$, $60 = 53 + 7$, $6 = 98 - 92$, $68/4 = 17$, $1024/512$, $3 \times 4 = 24/2$, $17 + 28 = 5 \times 9$
Places: Benin, Tonga, Malawi, Tutulia, Sarawak, Curacao, Monclova, Kiribati, Caledonia, Nagercoil

Numbers/Letters (preliminary study)
Numbers: 111, 222, 33333, 4444, 5555, 666, 77777, 88888, 9999, 0000
Letters: one, two, three, four, five, six, seven, eight, nine, zero

Science/Arts (Study 1)
Science: science, technology, physics, chemistry, Einstein, NASA, experiment, astronomy
Arts: poetry, art, Shakespeare, dance, literature, novel, symphony, drama

Mathematics/Arts (Studies 1 and 2)
Mathematics: math, algebra, geometry, calculus, equations, computation, numbers, Newton
Arts: poetry, art, Shakespeare, dance, literature, novel, symphony, drama

I/They (Studies 1 and 2)
I: I, me, myself, mine
They: they, them, their, theirs

Masculine/Feminine (Study 2)
Masculine: brother, father, uncle, grandfather, son, he, his, him
Feminine: sister, mother, aunt, grandmother, daughter, she, hers, her

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