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A Meta-Analysis of the Relationship Between Anxiety Toward Mathematics and Achievement in Mathematics

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In this meta-analysis I examined 26 studies on the relationship between anxiety toward mathematics and achievement in mathematics among elementary and secondary students. The common population correlation for the relationship is significant (–.27). A series of general linear models indicated that the relationship is consistent across gender groups, grade-level groups, ethnic groups, instruments measuring anxiety, and years of publication. The relationship, however, differs significantly among instruments measuring achievement as well as among types of publication. Researchers using standardized achievement tests tend to report a relationship of significantly smaller magnitude than researchers using mathematics teachers' grades and researcher-made achievement tests. Published studies tend to indicate a significantly smaller magnitude of the relationship than unpublished studies. There are no significant interaction effects among key variables such as gender, grade, and ethnicity.

Key Words: Achievement; Anxiety; Meta-analysis; Review of research; Secondary, 5–12

There is an increasing recognition that affective factors play a critical role in the teaching and learning of mathematics (McLeod, 1992, 1994). One affective factor that "has probably received more attention than any other area that lies within the affective domain" is anxiety toward mathematics (McLeod, 1992, p. 584). Aiken (1960) considered mathematics anxiety a "relative" of the general attitude toward mathematics, only being more visceral. Most researchers, however, consider mathematics anxiety to be a construct that is distinct from attitude toward mathematics. For example, McLeod (1992) stated that the term *attitude* "does not seem adequate to describe some of the more intense feelings that students exhibit in mathematics classrooms" (p. 576), such as anxiety, confidence, frustration, and satisfaction. Mathematics anxiety is often referred to as "the general lack of comfort that someone might experience when required to perform mathematically" (Wood, 1988, p. 11) or the feeling of tension, helplessness, and mental disorganization one has when required to manipulate numbers and shapes (Richardson & Suinn, 1972; Tobias, 1978). Mathematics anxiety can take multidimensional forms including, for example, dislike (an attitudinal element), worry (a cognitive element), and fear (an emotional element) (see Hart, 1989; Wigfield & Meece, 1988).

Spielberger (1972) conceptualized anxiety as a state, a trait, and a process. Through his model of anxiety-as-process, he explained anxiety as a result of a chain reaction that consisted of a stressor, a perception of threat, a state reaction, cognitive reappraisal, and coping. Cemen (1987) also defined *mathematics anxiety* as an anxious state in response to mathematics-related situations that are perceived as threatening to self-esteem. In her model of mathematics anxiety reaction, environmental antecedents (e.g., negative mathematics experiences, lack of parental encouragement), dispositional antecedents (e.g., negative attitudes, lack of confidence), and situational antecedents (e.g., classroom factors, instructional format) are seen to interact to produce an anxious reaction with its physiological manifestations (e.g., perspiring, increased heart beat).

Although the search for causes of mathematics anxiety is often unsuccessful (Gough, 1954), many researchers have reported the consequences of being anxious toward mathematics, including the inability to do mathematics, the decline in mathematics achievement, the avoidance of mathematics courses, the limitation in selecting college majors and future careers, and the negative feelings of guilt and shame (Armstrong, 1985; Betz, 1978; Brush, 1978; Burton, 1979; Donady & Tobias, 1977; Hendel, 1980; Preston, 1986/1987; Richardson & Suinn, 1972; Tobias & Weissbrod, 1980). Therefore, not only are the professional and economic gains that would result from changing mathematics anxiety into mathematics confidence indispensable, the psychological boost that individuals experience when they are successful in mathematics is also important (National Research Council, 1989).

Theoretical models of the relationship between anxiety toward mathematics and achievement in mathematics are complicated to establish (Gliner, 1987; Mevarech & Ben-Artzi, 1987), but researchers have demonstrated various characteristics of the relationship. The traditional arousal theorists state that there exists an optimal level of arousal around the middle of the arousal dimension—optimal both in terms of performance and in the sense of hedonic tone (being most pleasant, see Hebb, 1955). This idea is often graphically represented as an inverted-U curve depicting a curvilinear relationship between anxiety and performance. Thus, this arousal theory indicates that some anxiety is beneficial to performance, but after a certain point it undermines performance. Most researchers, however, start with the linear notion that anxiety seriously impairs performance (see Lazarus, 1974). Specifically, a higher level of anxiety is associated with a lower level of achievement. This negative relationship has been displayed across several age populations. For example, mathematics anxiety is negatively correlated with mathematics performance among adults in general (Quilter & Harper, 1988) and among college students in particular (Betz, 1978; Frary & Ling, 1983). In his meta-analysis, Hembree (1990) reported an average correlation of –.31 between anxiety and achievement for college students.

This negative relationship also appears at the elementary and secondary school levels (e.g., Chiu & Henry, 1990; Lee, 1991/1992; Meece, Wigfield, & Eccles, 1990). Hembree (1990) reported an average correlation of –.34 for school students, concluding that mathematics anxiety seriously constrains performance in mathematical tasks and that reduction in anxiety is consistently associated with improvement in achievement. Mathematics anxiety is usually associated with mathematics achievement individually but not necessarily collectively. For example, a student's level of mathematics anxiety can significantly predict his or her mathematics performance (Fennema & Sherman, 1977; Hendel, 1980; Rounds & Hendel, 1980; Wigfield & Meece, 1988). But when the effects of previous mathematics performance, attitude toward mathematics, and mathematics self-concept are controlled, the influence of mathematics anxiety becomes either nonsignificant or substantially reduced (Betz, 1978; Brush, 1980; Fennema & Sherman, 1977; Rounds & Hendel, 1980; Siegel, Galassi, & Ware, 1985).

The theoretical explanation of the negative relationship stems mainly from the theory of test anxiety. Some researchers have regarded mathematics anxiety as a kind of subject-specific test anxiety (e.g., Brush, 1981). Although others have argued that mathematics anxiety may be a psychologically different construct from test anxiety (e.g., Richardson & Woolfolk, 1980), "a tacit belief has seemed to prevail that test-anxiety theory can be used to support both constructs" (Hembree, 1990, p. 34). Two theoretical models have been influential in the research on mathematics anxiety. In the interference model, based on the work of Liebert and Morris (1967), Mandler and Sarason (1952), and Wine (1971), researchers have described mathematics anxiety as a disturbance of the recall of prior mathematics knowledge and experience. Consequently, a high level of anxiety causes a low level of achievement. In the deficits model, Tobias (1985) regarded mathematics anxiety as the remembrance of poor mathematics performance in the past and believed that poor performance causes high anxiety. According to this deficits model, a student's low level of mathematics achievement is attributed to poor study habits and deficient test-taking skills instead of to mathematics anxiety. Some have made theoretical efforts to integrate these competing frameworks; one result was the "limited cognitive capacity formulation" (see Tobias, 1985, p. 138).

Some researchers have attempted to introduce mediating variables, such as gender, age, and race-ethnicity, into the theoretical models of the relationship. For example, Eccles and Jacobs (1986) suggested that gender differences in mathematics anxiety are attributable to gender differences in mathematics achievement. Aiken (1970) stated that "no one would deny that sex can be an important moderator variable in the predication of achievement from measures of attitudes and anxiety" (p. 567). Hembree (1990) found that mathematics anxiety increases during junior high grades, reaches its peak in Grades 9 and 10, and levels off during senior high grades, implying that the relationship is a function of grade levels. Aiken also concluded that the correlation between performance in mathematics and anxiety toward mathematics is much stronger at the junior high level. Engelhard (1990) showed that the correlation between mathematics anxiety and mathematics achievement is higher among American students than among Thai students, indicating that the same level of anxiety tends to be associated with achievement of American students more strongly than with achievement of Thai students. McLeod (1992) concluded that "it seems reasonable to hypothesize that affective factors are particularly important to differences in performance between groups that come from different cultural backgrounds" (p. 587). Lacking in the theoretical models, however, are variables that depict the genesis of mathematics anxiety, the nature of treatment for mathematics anxiety, and the utility of mathematics anxiety to improve mathematics performance (Betz, 1978).

There have been few systematic reviews of research on mathematics anxiety. Leder (1987), McLeod (1992, 1994), and Reyes (1980, 1984) reviewed the affective domain as it relates to the cognitive domain in mathematics, but their discussions on mathematics anxiety are quite limited. On the basis of a review of a number of studies concerning gender differences in mathematics anxiety, Hunt (1985) concluded that there are evident differences between males and females in mathematics anxiety and that researchers need to examine the reason females are more anxious about mathematics than their male counterparts. Later, some researchers conducted a meta-analysis of the same studies and reached a different conclusion; they found that gender differences are small in size but that when differences do exist, females show more anxiety than males (Hyde, Fennema, Ryan, Frost, & Hopp, 1990). Wood (1988) reviewed research on mathematics anxiety manifested among elementary teachers and suggested that mathematics teachers' anxiety toward mathematics was likely to be transmitted to their students.

There have been even fewer systematic reviews of the relationship between mathematics anxiety and mathematics achievement. Aiken (1970), in his narrative review, highlighted a weak, though statistically significant, negative relationship; he noticed that the magnitude of the relationship is usually somewhat smaller in absolute value than that of the relationship between attitude toward mathematics and achievement in mathematics. Hembree (1990), in his meta-analysis, did not focus on the relationship between mathematics anxiety and mathematics achievement, although some analyses were done on that topic, and he concluded that there exists a significant but negative relationship. However, because it was based on 58 studies on college students but only 7 studies on elementary and secondary students, Hembree's conclusion seems to apply more to college students than to precollege students.

In his meta-analysis Hembree (1990) displayed a simplified picture of the relationship between mathematics anxiety and mathematics achievement. Many issues basic to this relationship, however, remain unclear. There is a need to locate more research on this relationship and display further the characteristics of the relationship. Both theoretical and practical work can benefit from, for example, a comprehensive review of gender differences in the relationship and a study of changes in the relationship as students progress through school. The main research questions of my meta-analysis are (a) What is the magnitude of the relationship between anxiety toward mathematics and achievement in mathematics? and (b) How does the magnitude of the relationship fluctuate in response to various study features such as gender, grade level, ethnicity, instruments used to measure anxiety and achievement, year of publication, and type of publication?

METHOD

Sample of Studies

Although Aiken and Dreger (1961) have demonstrated that it is possible to construct an inventory to measure mathematics-related anxiety, instruments that were developed for this purpose in the 1960s might be considered primitive. For example, the item response theory (IRT), an important statistical method used to examine the psychometric properties of response data, was not well developed until the 1970s. Effective IRT software programs were developed even later. To increase the accuracy of measurement in this meta-analysis, I examined studies reported after 1975 because attitudinal instruments have been greatly refined since the late 1970s (Pedersen, Bleyer, & Elmore, 1985).

I used a three-step approach to search for relevant studies on the relationship between mathematics anxiety and mathematics achievement. First, to promote a broad search of several computerized databases for the years 1975 through the present, I used the key topic-related descriptors (*mathematics, achievement,* and *anxiety*) as independent words (see Dusek & Joseph, 1983). The databases searched were (a) Educational Resources Information Center (ERIC), (b) Psychological Abstracts (PSY), (c) Dissertation Abstracts International (DAI), and (d) International ERIC, which comprises Australian Education Index (AEI), British Education Index (BEI), and Canadian Education Index (CEI).

The next step was to find, on the basis of the same descriptors, both qualitative and quantitative reviews published since 1975 as a means to enrich the pool of studies. Reference lists from Aiken (1976), Hembree (1990), Hunt (1985), Hyde, Fennema, and Lamon (1990), Leder (1987), McLeod (1992, 1994), Reyes (1980, 1984), and Wood (1988) were checked for relevant studies. Finally, I conducted a manual search of seven leading journals in education, particularly in mathematics education, for the years 1975 through the present. These journals were *American Educational Research Journal, Educational Studies in Mathematics, Journal for Research in Mathematics Education, Journal of Educational Psychology, Journal of Educational Research, Review of Educational Research,* and *School Science and Mathematics.*

Using this search procedure, I located many journal articles, dissertations, and ERIC documents on various aspects of the topic, then studied the abstracts to screen all the studies. I obtained and read promising studies and those that could not be evaluated from their abstracts. A study was included in this meta-analysis if it (a) was an investigation of the relationship between mathematics anxiety and mathematics achievement, (b) did not have any experimental interventions on either anxiety or achievement, (c) reported on students at the elementary or secondary school level, and (d) reported quantitative data in sufficient detail for calculation of effect size. On the basis of these criteria, I selected 26 individual studies for this meta-analysis.

Coding of Selected Studies

Each study was coded for several independent variables that depicted design features as well as for author(s), year of publication, and type of publication. Design features included gender, grade, ethnicity, sample size, and instruments used to measure anxiety and achievement. The coding of the 26 individual studies is reported in Table 1.

The dependent variable was effect size, indicating the relationship between anxiety toward mathematics and achievement in mathematics. Because researchers in all selected individual studies used correlation coefficients to describe the relationship, in this meta-analysis I used the common metric of r as its effect-size measure (see Rosenthal, 1991). One effect size was obtained from each study unless the study contained independent samples to measure the relationship. Gender groups, grade levels (in cross-sectional designs), and ethnic groups in a single study were considered separate primary studies (L. V. Hedges, personal communication, 1987, cited in Hyde, Fennema, & Lamon, 1990).

Table 1
Descriptive Information of Studies on the Relationship Between Anxiety Toward Mathematics and Achievement in Mathematics (in Chronological Order)

Study	Effect size	Study feature	Instrument
Sepie & Keeling, 1978	–.28	$N = 132$, Grade 6, male, New Zealander	MASC/PAT
Sepie & Keeling, 1978	–.30	$N = 114$, Grade 6, female, New Zealander	MASC/PAT
Sandman, 1979	–.47	$N = 184$, Grade 8	MAI/MAT
Sandman, 1979	–.17	$N = 229$, Grade 11	MAI/MAT
Brassell, Petry, & Brooks, 1980	–.30	$N = 714$, Grade 7	MAI/CTBS
Suinn & Edwards, 1982	–.59	$N = 28$, Grades 7–11	MARS-A/MTG
Suinn & Edwards, 1982	–.20	$N = 1009$, Grade 12	MARS/MTG
Saigh & Khouri, 1983	–.60	$N = 73$, Grades 9–12, male, Lebanese	MARS/MTG
Saigh & Khouri, 1983	–.48	$N = 60$, Grades 9–12, female, Lebanese	MARS/MTG
Eccles & Jacobs, 1986	–.17	$N = 164$, Grades 7–9	RMQ/SAT-M
Donnelly, 1987	–.85	$N = 177$, Grade 10	MARS/CAT
Gliner, 1987	–.12	$N = 95$, Grades 9–12	MARS/CTBS
Wahl, 1987	–.31	$N = 59$, Grade 8	MARS/MTG
Suinn, Taylor, & Edwards, 1988	–.28	$N = 105$, Grades 4–6, Hispanic	MARS/SAT
Wigfield & Meece, 1988	–.22	$N = 564$, Grades 6–12, Year 1, White	MAQ/MTG
Wigfield & Meece, 1988	–.26	$N = 564$, Grades 6–12, Year 2, White	MAQ/MTG
Wither, 1988	–.51	$N = 271$, Grade 10, male, Australia	MARS/MTG
Wither, 1988	–.24	$N = 245$, Grade 10, female, Australian	MARS/MTG
Reavis, 1989	–.28	$N = 407$, Grades 9–12, White	MAS/SAT
Suinn, Taylor, & Edwards, 1989	–.31	$N = 1119$, Grades 4–6	MARS/SAT
Baya'a, 1990	–.42	$N = 418$, Grades 9–12, Israeli	MARS/MTG
Chiu & Henry, 1990	–.37	$N = 50$, Grade 5	MASC/MTG
Chiu & Henry, 1990	–.24	$N = 56$, Grade 6	MASC/MTG

Table 1, continued
Descriptive Information of Studies on the Relationship Between Anxiety Toward Mathematics and Achievement in Mathematics (in Chronological Order)

Study	Effect size	Study feature	Instrument
Chiu & Henry, 1990	−.47	$N = 115$, Grade 8	MASC/MTG
Engelhard, 1990	−.24	$N = 4091$, Grade 8	SIMS-AS/SIMS
Engelhard, 1990	−.14	$N = 3613$, Grade 8, Thai	SIMS-AS/SIMS
Meece, Wigfield, & Eccles, 1990	−.13	$N = 250$, Grades 7–9, Year 1, White	MAQ/RMT
Meece, Wigfield, & Eccles, 1990	−.21	$N = 250$, Grades 7–9, Year 2, White	MAQ/RMT
Bieschke & Lopez, 1991	−.51	$N = 289$, Grade 10	MAS/SAT-M
Bush, 1991	.49	$N = 584$, Grades 4–6, concept	MARS/ITBS
Bush, 1991	.19	$N = 584$, Grades 4–6, application	MARS/ITBS
Cooper & Robinson, 1991	−.47	$N = 290$, Grade 12, White	MAS/MMPT
Green, 1991	−.35	$N = 496$, Grades 7–12, Australian	MAS/MTG
Mevarech, Silber, & Fine, 1991	−.44	$N = 149$, Grade 6, Israeli	RMQ/AAT
Thorndike-Christ, 1991	−.47	$N = 1516$, Grades 6–12	MAS/MTG
Hadfield, Martin, & Wooden, 1992	−.23	$N = 358$, Grades 8–10, Native American	MARS/CTBS
Lee, 1992	−.27	$N = 255$, Grade 6	MAS/MTG

Note. In the column of instrument, the slash separates anxiety instrument from achievement instrument. For anxiety instrument, MAI = Mathematics Attitude Inventory, MAQ = Mathematics Anxiety Questionnaire, MARS = Mathematics Anxiety Rating Scale, MAS = Mathematics Anxiety Scale, MASC = Mathematics Anxiety Scale for Children, RMQ = researcher-made questionnaire, and SIMS-AS = Second International Mathematics Study-Anxiety Scale. For achievement instrument, AAT = Arithmetic Achievement Test, CAT = California Arithmetic Test, CTBS = Comprehensive Test of Basic Skills, ITBS = Iowa Test of Basic Skills, MAT = Mathematics Achievement Test, MMPT = Missouri Mathematics Placement Test, MTG = mathematics teacher grading, PAT = Progressive Achievement Test, RMT = researcher-made test, SAT = Stanford Achievement Test, SAT-M = Scholastic Aptitude Test-Mathematics, SIMS = Second International Mathematics Study.

Meta-analytic methodology literature is not explicit on the use of longitudinal studies. Longitudinal data can be viewed as being within a single study in which correlations are aggregated to represent the effect size of the study. Willett and Singer (1991) argued, however, that “a complex longitudinal time-dependent process cannot be adequately summarized by a single statistic” (p. 430). In line with this argument, longitudinal data in a study were treated as several independent primary studies based on different grade levels. Using this treatment, I maintain a clear identity or an explainable background for each effect size at the primary-study level so that statistical results are easy to interpret and understand.

Characteristics of the Sample

The sample of 26 studies included 18 published articles, 3 unpublished articles, and 5 dissertations. The published studies appeared in 14 journals. Among the 26 studies, 21 were published after 1985. The median year of publication was 1991. In total, 6 instruments were used to measure anxiety, with the Mathematics Anxiety Rating Scale (MARS) as the most frequently used one (in 12 of 26 studies), and 9 instruments were used to measure achievement in mathematics. A total of 18 279 students across Grades 5 to 12 participated in these studies. The largest sample size was 4 091, and the smallest sample size was 28. The studies had an average of 703 students per sample. Most studies were mixed in terms of gender, grade, and ethnicity. The 26 studies generated 37 effect sizes for this meta-analysis.

Statistical Procedure

Variation among effect sizes was examined through Hedges's Q test of homogeneity (Hedges & Olkin, 1985). This test was used to determine whether population effect sizes were relatively consistent across unweighted effect sizes. If the test showed a nonsignificant Q value, which indicated that effect sizes were homogeneous, effect sizes were then combined following procedures of combining estimates of correlation coefficients (Hedges & Olkin, 1985). If the test showed a significant Q value, which indicated that effect sizes were heterogeneous, I took Hembree and Dessart's (1986) suggestion to delete outliers repeatedly until the remaining effect sizes became homogeneous.

When effect sizes are homogeneous, the population correlation can be determined by predictor variables. The substantive rationale is that studies differ because of different research design characteristics (Hedges & Olkin, 1985). In this study I fitted homogeneous effect sizes into a general linear regression model through which I examined the effects of a number of independent variables on the relationship between mathematics anxiety and mathematics achievement. I employed the weighted least-squares procedures for fitting general linear models to correlations as outlined by Hedges and Olkin. Sample size was used to create weight for the regression analysis (see Hedges & Olkin, 1985) but was not entered into the regression equation (see Schram, 1996).

To better illustrate the overall effect (population coefficient) in this meta-analysis, I used the percentage of distribution nonoverlap, or the U_3 statistic (Cohen, 1977), to denote the percentage of participants in the group with the larger anxiety mean whose achievement scores were exceeded by the achievement scores of half the participants in the group with the smaller anxiety mean. If the dependent variable was standardized, the U_3 statistic also indicated the change in scores or percentiles when a participant moved from one group to the other.

RESULTS

Overall Effects

The test of homogeneity of the 37 effect sizes was significant. Three evident outliers were deleted: –.84 in Donnelly (1986/1987) as well as .49 and .19 in Bush (1991). The removal of these outliers significantly improved the homogeneity of the remaining effect sizes. The homogeneity test was not significant at the .01 level ($Q = 55.82$, $df = 33$). Effect sizes were then combined with respect to their sample sizes. The weighted estimator of population correlation was –.27, which was significant at the .01 level, indicating that it was unlikely (likelihood less than 1 time in 100) that the observed significance of this population correlation occurred by chance alone.

The U_3 statistic corresponding to a population correlation of −.27 is .71. To understand the meaning of the U_3 statistic, one should imagine that all the students are classified into two groups according to their levels of mathematics anxiety. One group has low mathematics anxiety; the other has high mathematics anxiety. Then, the U_3 statistic of .71 indicates that the average student in the group of low mathematics anxiety would have a score in mathematics achievement that is greater than the scores of 71% of the students in the group of high mathematics anxiety. Expressed another way, measures (or treatments) that resulted in movement of a typical student in the group of high mathematics anxiety into the group of low mathematics anxiety would be associated with improvement of the typical student's level of mathematics achievement from the 50th to the 71st percentile.

Inasmuch as the effect sizes all shared the same population correlation, variation among effect sizes existed mainly because studies differed according to a number of research design characteristics. A general linear regression was used to model this variation. Using the general linear model enabled me to identify the significant variables responsible for the variation among effect sizes and to gain insight into several practical concerns, such as gender differences and age differences, regarding the relationship between mathematics anxiety and mathematics achievement. Table 2 displays the models considered in this meta-analysis.

Table 2
Selected Models From the General Linear Regression Analysis of the Relationship Between Anxiety Toward Mathematics and Achievement in Mathematics

Model	Regression test Q_R	Regression test *df*	Residual test Q_E	Residual test *df*
Gender effect (2 vectors: male vs. female; mixed vs. female)	17.74***	2	214.01***	31
Grade effect (2 vectors: Grades 4–6 vs. 10–12; Grades 7–9 vs. 10–12)	18.34***	2	213.41***	31
Race-ethnicity effect (1 vector: mixed vs. unmixed)	16.50***	1	215.25***	32
Anxiety instrument (1 vector: MARS vs. others)	4.43*	1	227.32***	32
Achievement instrument (1 vector: psychometric vs. nonpsychometric)	36.19***	1	195.56***	32
Publication type (2 vectors: published and dissertation vs. unpublished)	78.07***	2	153.68***	31
Publication year (continuous variable)	0.28	1	231.48***	32
Gender, grade, race, anxiety/achievement instrument, publication type/year	133.58***	10	98.17***	23

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

Effect of Gender

Effect coding (see Cohen & Cohen, 1983) was used to create two variables. The female group was used as the baseline against which the male group and the mixed group were compared. Table 2 shows that the Q statistic (the weighted sums of squares) for gender effects explains a statistically significant amount of the variability in the effect sizes (Q_R = 17.74, df = 2). However, this amount is a trivial portion of the total variance (231.75); thus the Q statistic for error is statistically significant (Q_E = 214.01, df = 31). The two gender-related variables did not have appreciable effects on the magnitude of the relationship (regression coefficient, β, = –0.12; standard error, *SE*, = 0.09 for the male vs. female comparison). This finding indicates that the relationship between mathematics anxiety and mathematics achievement was similar for males and females.

Effects of Grade Level

Three grade-level groups were formed in this meta-analysis: Grades 4 through 6, Grades 7 through 9, and Grades 10 through 12 (there were no studies examining the relationship in Grades 1, 2, or 3). Effect sizes were effect coded so that the relationship in Grades 10 through 12 was the baseline against which the relationships in Grades 4 through 6 and Grades 7 through 9, respectively, were compared. As did gender effects, grade effects accounted for a very small, though statistically significant, percentage of the total variance. The Q statistic for error remained substantial (Q_E = 213.41, df = 31). Grade levels did not have statistically significant effects on the relationship between mathematics anxiety and mathematics achievement (for the Grades 4 through 6 vs. Grades 10 through 12 comparison: β = –0.02, *SE* = 0.03; for the Grades 7 through 9 vs. Grades 10 through 12 comparison: β = 0.05, *SE* = 0.04). Therefore, the relationship was consistent across the three grade-level groups.

Effects of Ethnicity

Because few ethnic groups were involved in the selected studies, it was impossible to classify effect sizes into conventional ethnic groups (White, Black, etc.). Instead, in this meta-analysis, I compared the magnitude of the relationship between mixed and unmixed ethnic groups. *Dummy coding* (see Cohen & Cohen, 1983) was used to represent this variable, which, as shown in Table 2, explains a very small, though statistically significant, amount of the total variance in the effect sizes (Q_E = 215.25, df = 32). This small effect (β = –0.06, *SE* = 0.04) indicated that the relationship was consistent between mixed and unmixed ethnic groups.

Effects of Instrument Measuring Mathematics Anxiety

Because the Mathematics Anxiety Rating Scale (MARS) was employed to measure mathematics anxiety in many studies, in this meta-analysis I created a dummy variable to compare the effect of the MARS with that of other instruments (as the baseline effect) used to measure mathematics anxiety. Table 2 shows the effects of instruments on the relationship between mathematics anxiety and mathematics achievement. Instruments explained a trivial amount of variance (Q_R = 4.43, df = 1) and had a very small effect (β = –0.04, *SE* = 0.05). This finding indicates that the relationship was consistent between studies using the MARS and those using other instruments to measure mathematics anxiety.

Effects of Instrument Measuring Mathematics Achievement

Quite diverse instruments were used to measure mathematics achievement in the selected studies. However, there was a balance between use of commercially developed instruments and other instruments including researcher-designed mathematics tests and mathematics teachers' grades. A dummy variable was created with instruments that are commercially developed as the baseline effect. This variable seems to be a better predictor than previous variables ($Q_R = 36.19$, $df = 1$), although the Q statistic for error is still substantial ($Q_E = 195.56$, $df = 32$). This variable also had a statistically significant effect on the relationship between mathematics anxiety and mathematics achievement at the .05 level ($\beta = -0.09$, $SE = 0.04$). Therefore, studies in which standardized achievement tests (the commercially developed instruments) were used showed a significantly smaller magnitude of the relationship than studies in which researcher-made achievement tests and mathematics teachers' grades were used as achievement measures.

Effects of Type of Publication

The type of publication comprises three categories: published article, dissertation, and unpublished article. Using published articles as the baseline effect, I used effect coding to create two variables (see Table 2). The Q statistic shows that this model explains a statistically significant amount of the total variation in the effect sizes ($Q_R = 78.07$, $df = 2$). This model is the best individual model because it explains the greatest amount of total variance. One of the two variables (unpublished vs. published) was statistically significant at the .05 level ($\beta = -0.12$, $SE = 0.04$); the other variable (dissertation vs. published) was not statistically significant ($\beta = 0.04$, $SE = 0.06$). Therefore, published articles showed a significantly smaller magnitude of the relationship than unpublished articles, whereas published articles and dissertations showed similar magnitudes of the relationship.

Effects of Year of Publication

The year of publication was used as a continuous variable in the general linear model. It is the only variable that explained little (a statistically nonsignificant amount) of the total variance ($Q_R = 0.28$, $df = 1$). Year of publication also showed no effect on the relationship between mathematics anxiety and mathematics achievement ($\beta = -0.00$, $SE = 0.01$). This finding indicates that studies from different periods of time showed consistent effect sizes.

Interaction Effects

A series of general linear models containing interaction terms were tested to examine whether the effect of one variable depends on the levels of another variable (these models are not shown in Table 2). The interactions between gender and grade ($Q_R = 8.19$, $df = 1$), between grade and ethnicity ($Q_R = 12.79$, $df = 2$), as well as between anxiety instrument and achievement instrument ($Q_R = 4.91$, $df = 1$) were not statistically significant. However, the interaction between publication year and publication type explained a statistically significant amount of the total variance in the effect sizes ($Q_R = 80.83$, $df = 2$). Results show that the differences in effect sizes between published and unpublished articles decreased over time in the period examined in this meta-analysis.

The Final Model

The final model included all variables discussed in individual models. The Q statistic indicates that this final model explains a statistically significant and practically substantial amount of variance in the effect sizes ($Q_R = 133.58$, $df = 10$). A total of 58% of the variance among effect sizes was accounted for in this final model. In terms of regression coefficients, the variable that compares unpublished with published articles is the only statistically significant variable in the model ($\beta = -0.16$, $SE = 0.06$, $p = .011$), indicating that published articles reported a significantly weaker relationship between mathematics anxiety and mathematics achievement than unpublished articles. Because of the statistically significant interaction between year of publication and type of publication discussed earlier, I attempted to include this interaction term in the final model. The resultant model, however, differed very little from the final model in Table 2, in terms of the fitting statistics. For simplicity that interaction term was then removed from the final model.

DISCUSSION

Principal Findings

In this meta-analysis I demonstrate that the common population correlation for the relationship between anxiety toward mathematics and achievement in mathematics was –.27. A series of general linear models were fitted to examine the major research design characteristics that determine the variation among effect sizes. Results show that the relationship between mathematics anxiety and mathematics achievement is consistent across gender groups (male, female, and mixed), grade-level groups (Grades 4 through 6, Grades 7 through 9, and Grades 10 through 12), ethnic groups (mixed and unmixed), instruments used to measure anxiety (MARS and others), and years of publication. The relationship, however, differs significantly between types of instruments used to measure achievement as well as among types of publication. Researchers using standardized achievement tests tended to report a significantly weaker relationship than those using researcher-made achievement tests and mathematics teachers' grades. Published studies tended to indicate a significantly weaker relationship than unpublished studies. There were no statistically significant interaction effects among key variables such as gender, grade, and ethnicity.

Theoretical and Practical Implications

This meta-analysis shows support for the findings of significance of the relationship between mathematics anxiety and mathematics achievement for school students, as previously reported (e.g., Armstrong, 1985; Eccles, 1985; Hackett, 1985; Wigfield & Meece, 1988). More important, in this meta-analysis I have quantified the potential improvement in mathematics achievement when mathematics anxiety is reduced. Hembree (1990) concluded that as psychological treatments, systematic desensitization and "anxiety management training and conditional inhibition were highly successful in reducing mathematics anxiety levels" (p. 43). The current meta-analysis further indicates that such a reduction may be associated with an improvement from the 50th to 71st percentile in mathematics achievement for an average student highly anxious about mathematics. This amount of improvement is substantial according to any threshold standards in behavioral sciences (see Cohen & Cohen, 1983).

This meta-analysis has important implications for educational intervention. Those advocating treatment programs, such as self-management of emotional stress, for students with mathematics anxiety have traditionally emphasized affective factors only (see Richardson & Woolfolk, 1980). Although various treatment programs appear to be effective in reducing mathematics anxiety (Hembree, 1990), in few has attention been paid to the role of cognitive factors such as skill development. The significant, negative association between mathematics achievement and mathematics anxiety, as reported in this meta-analysis, indicates the potential value of cognitively based treatments. That is, measures or treatments that help students overcome their cognitive difficulties in the learning of mathematics may be associated with an appreciable reduction in mathematics anxiety. There has been effort to include a stronger cognitive orientation in the research of mathematics anxiety because of the finding that cognitive style is associated with mathematics anxiety (e.g., Hadfield & Maddux, 1988). For example, Hunsley (1987) found that mathematics anxiety is related to cognitive factors such as pessimistic post-exam appraisals and negative internal dialogues. Handler (1990) suggested that a cognitive process approach reduces mathematics anxiety through (a) making knowledge work for the learner, (b) joining skill and content, (c) linking motivation to cognition, and (d) using social communities. By taking cognitive factors into account, program developers may well improve the effectiveness of various treatment programs for mathematics anxiety.

Researchers recognize that the nature of the relationship between mathematics anxiety and mathematics achievement is not clear (see Reyes, 1984). In this meta-analysis I attempted to partially unfold the "mystery" by breaking the effect sizes of the relationship into categories and examining the differences among those categories. I see implications related to several key issues in this area. First, in this meta-analysis I found no significant gender differences on the relationship between mathematics anxiety and mathematics achievement. Ma and Kishor (1997) reported a similar finding—that the relationship between attitude toward mathematics and achievement in mathematics is the same for males and females. These findings do not support Aiken's (1970) conclusion that "measures of attitudes and anxiety may be better predictors of the achievement of females than of males" (p. 567).

Another important issue is the developmental characteristics of the relationship. In this meta-analysis I studied three grade-level groups (Grades 4 through 6, Grades 7 through 9, and Grades 10 through 12) and found that the relationship between mathematics anxiety and mathematics achievement is significant from Grade 4 on. This finding seems reasonable because mathematics anxiety can arise at any time during schooling (see Lazarus, 1974). But this meta-analysis further shows that once mathematics anxiety takes shape, its relationship with mathematics achievement is consistent across grade levels. This finding, when considered together with reports that uneasiness, worry, and anxiety associated with the learning of mathematics increase during the early adolescent years (e.g., Brush, 1985; Hembree, 1990; Meece, 1981; Wigfield & Meece, 1988), implies that an increasing decline in mathematics achievement during early secondary schooling is possible for adolescent students with mathematics anxiety. For these students, one way to avoid high mathematics anxiety and poor mathematics achievement is to avoid mathematics courses, particularly advanced courses (e.g., Armstrong, 1985; Cemen, 1987). Early detection of mathematics anxiety leads to implementation of effective treatment programs (e.g., Betz, 1978; Lazarus, 1974; McMillan, 1976). This meta-analysis indicates that screening and treatment programs should be introduced during the upper elementary grades (Grades 4 through 6).

Comparisons of the relationship between mathematics anxiety and mathematics achievement among ethnic groups are rare in the literature. Because of the sparse data on this issue, I could not compare this relationship among ethnic groups in this meta-analysis. I did, however, find that researchers studying participants of varied ethnic backgrounds tended to find a relationship similar to that found by researchers who studied participants with homogeneous ethnic backgrounds. This result indicates that the ethnic formation of a sample does not bias the relationship. It also raises the likelihood that there may not be significant ethnic differences in the relationship. More studies are needed to examine the relationship from the racial-ethnic perspective before one can conclude that measures of anxiety toward mathematics may predict the level of mathematics achievement equally well across ethnic groups.

Comments on the Instruments

Instruments are especially important in the research of the relationship between the affective and cognitive domains. Ma and Kishor (1997) used a meta-analysis to examine the relationship between attitude toward mathematics and achievement in mathematics. Reporting weak mean effect sizes, they suggested that current instruments measuring attitude toward mathematics seem unable to capture what constitutes a "true" attitude. The average population correlation in the current meta-analysis was relatively much stronger (see Cohen & Cohen, 1983). This finding indicates that current instruments used to measure mathematics anxiety are more effective than those used to measure attitude. Perhaps anxiety toward mathematics is easier to measure than attitude toward mathematics in that it is more operationally definable for researchers and more verbally expressible for students. But, "the preciseness with which pupils can express their attitudes varies with level of maturity" (Aiken, 1970, p. 558).

This meta-analysis also shows that researchers using the MARS reported a relationship between mathematics anxiety and mathematics achievement similar to that reported by researchers using other instruments. This consistency among instruments with respect to anxiety may have something to do with their strong correlations. For example, Dew, Galassi, and Galassi (1983, 1984) found that the correlation is .68 between MAS and MARS and .78 between MAS and MAI. Note that these correlations are considered fairly strong from the perspective of behavioral sciences (see Cohen & Cohen, 1983). Thus, researchers' decisions on what instruments to use do not seem to affect analytic results found on the relationship. This conjecture certainly does not mean that all the instruments measure the same aspects of mathematics anxiety. I summarize the conceptual and operational aspects of various instruments in Table 3.

Mathematics anxiety often originates during students' early educational experiences (Chiu & Henry, 1990). But this meta-analysis shows that studies are rare in the early elementary grades, probably because of the lack of instruments that measure mathematics anxiety of children at the lower elementary level. Almost all existing instruments were originally designed for adults or secondary school students. A version of the MARS has been developed mainly for upper elementary school

Table 3
Summary of Instruments Measuring Anxiety Toward Mathematics (in Chronological Order)

Description of items	Number of items	Scale
Mathematics Anxiety Rating Scale (MARS) (Richardson & Suinn, 1972) Measures students' anxious reactions when they do mathematics in ordinary life and in academic situations	98	5-point Likert
Mathematics Attitude Inventory (MAI) (Sandman, 1974) Contains six scales, one of which is Anxiety Toward Mathematics, which measures students' mathematics anxiety in general academic situations	6	4-point Likert
Mathematics Anxiety Scale (MAS) (Fennema & Sherman, 1976) Measures students' feelings of anxiety and nervousness as well as associated somatic symptoms when students use mathematics	10	5-point Likert
Mathematics Anxiety Questionnaire (MAQ) (Meece, 1981) Measures cognitive and affective components of mathematics anxiety parallel to those of text anxiety: dislike, lack of confidence, discomfort, worry, fear and dread, and confusion and frustration	22	7-point Likert
Second International Mathematics Study Anxiety Scale (SIMS-AS) Measures the extent to which students feel afraid and scared of mathematics or feel calm and relaxed when they perform mathematical tasks	5	5-point Likert
Mathematics Anxiety Scale for Children (MASC) (Chiu & Henry, 1990) Describes various situations that can arouse mathematics anxiety—from getting a new mathematics textbook to taking an important test in a mathematics class	22	4-point Likert

students (see Suinn, Taylor, & Edwards, 1988). There is a need to develop new instruments that measure mathematics anxiety in the early elementary grades.

In many studies involved in Hembree's (1990) meta-analysis, mathematics achievement results were reported for subscales such as concepts, computation, and application. Because few studies in the current meta-analysis were reported this way, a general measure of mathematics achievement was used. The results indicated that studies using commercially developed achievement instruments reported a smaller magnitude of the relationship between mathematics anxiety and mathematics achievement than studies using mathematics teachers' grades and researcher-designed mathematics tests. This finding does not seem to support Hembree's conclusion that "grades in mathematics courses seemed depressed in relation to anxiety by about the same proportion as the students' test scores" (p. 38). Mathematics teachers' grades or researcher-designed mathematics tests appear to overestimate the relationship. One possible reason is that these measures lack control of the difficulty level of the items: The ceiling effect (items are so easy that many students perform well) or the floor effect (items are so difficult that many students perform poorly) is more likely to occur when mathematics teachers' grades or researcher-designed mathematics tests instead of commercial tests are used as achievement measures.

Unfolding the Anxiety-Achievement Dynamic in Mathematics

In a meta-analysis one usually does not pay much attention to outliers among effect sizes. However, an examination of outliers may sometimes have important theoretical or practical implications. Two of the three outliers in this meta-analysis are from studies by Bush (1991), who found a positive, significant relationship between mathematics anxiety and mathematics achievement and argued that mathematics anxiety tends to rise in students whose mathematics performance is improving. This result "represented a contradiction of previous research on the relationship between mathematics anxiety and achievement" (p. 42) probably because his sample of students had been extensively exposed to mathematics. They were either gifted students or students, in academic tracks, with intentions to enter a career for which they would need quantitative skills. These students are often able to control their anxiety and channel it into the task because of their strong self-esteem and high levels of task-related confidence (see Cemen, 1987). When this control occurs, students' anxiety actually facilitates their performance (Cemen, 1987). Instead of being an abnormal result, Bush's finding may be a hint that mathematics anxiety can be useful in promoting mathematics achievement. Therefore, through examining sample characteristics in studies by Bush, one can distinguish a special group of students whose mathematics performance benefits from a certain level of mathematics anxiety.

Resnick, Viehe, and Segal (1982) found that a decrease in mathematics anxiety is not associated with improvement in mathematics performance. This finding led them to doubt that the reduction in mathematics anxiety improves mathematics achievement. However, their sample was a group of college students with extensive mathematics backgrounds. Not only might the level of mathematics anxiety of those students be limited, but their mathematics achievement might also be high. This study thus demonstrates a unique relationship between mathematics anxiety and mathematics achievement for a specific group of students. Again, through examining participant characteristics in studies by Resnick et al., one can distinguish another group of individuals for whom higher mathematics performance is not associated with the reduction in mathematics anxiety.

The two examples above illustrate the dynamic nature of the relationship between mathematics anxiety and mathematics achievement. That is, the relationship can change dramatically for students with different social and academic background characteristics. These social and academic characteristics of students appear to be the key to unfolding this anxiety-achievement dynamic. When students' characteristics are diverse and unique, so are the relationships: Mathematics anxiety can facilitate mathematics performance, can debilitate mathematics performance, or can be unassociated with mathematics performance.

Results of this meta-analysis, considered together with the work of Buxton (1981), can be used to derive a psychological framework in which the relationship between mathematics anxiety and mathematics achievement can be understood as a psychological function of emotional reaction. Emotion, belief, and attitude are the major elements of the affective domain in the learning of mathematics (McLeod, 1992). Panic, fear, anxiety, and embarrassment have been identified as the results of emotional reaction to mathematical tasks (Buxton, 1981). McLeod described emotion as "hot" in that it "may involve little cognitive appraisal and may appear and disappear rather quickly" (p. 579). Emotional reaction to academic situations involving mathematics seems more likely to trigger mathematics anxiety that relates to mathematics performance than do both beliefs and attitudes that are considered "cold" and "cool" (see McLeod, 1992). Social and academic characteristics broaden the focus beyond psychological perspectives to anthropological and sociological perspectives. These characteristics mediate students' emotional reactions. In general, characteristics can be classified as personal (e.g., gender, age, ethnicity, and social class), environmental (e.g., social stereotypes, mathematics experiences, and parental encouragement), dispositional (e.g., attitude, confidence, and self-esteem), and situational (e.g., classroom factors, instructional format, and curricular factors) (see Cemen, 1987; Zaslavsky, 1994). In this meta-analysis I have examined some personal characteristics and found their mediation to be limited. This finding signals the need for inclusion of characteristics from other categories for further research. Overall, studies following this line of logic are likely to provide theoretical appreciation of the complexity of the relationship as well as practical implications for front-line educators.

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