Implicit Indicators of Women's Persistence in Math, Science, and Engineering

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The disproportionate dropout rate of female college students from math, science, and engineering (MSE) fields has recently received much attention (Brainard, Laurich-McIntyre, & Mobley, 1995; Carlin, 1997). The reasons for women's higher attrition rate from MSE fields remain unclear. Eighty 1st-year university students with a preexisting interest in MSE completed a computer task—the Implicit Association Test (IAT)—that measured identification with MSE, gender stereotypes regarding MSE, and attitudes toward MSE on an implicit, nonconscious level. Results indicated that women showed less implicit identification with MSE than did men, and that men showed stronger implicit stereotypes about MSE being "male" fields. Surprisingly, although men and women held negative implicit attitudes toward MSE, they did not differ significantly from each other in their implicit MSE attitudes. These results may have implications for better understanding women's persistence in MSE.

OVER THE PAST SEVERAL YEARS, THERE HAS been a growing interest in determining what factors influence the persistence and retention of female college students in math, science, and engineering (MSE). This interest stems, in part, from the observation that women continue to be underrepresented in MSE fields (Hackett & Betz, 1981; Seymour & Hewitt, 1994). One of the reasons for this underrepresentation may be due to the high attrition rate among women from these traditionally male-dominated disciplines. For example, the retention rate of women in college engineering programs has decreased significantly over the years. Although the national retention rate for women in engineering peaked at about 90% in 1972–76, this rate dropped to less than 60% by 1983–87 (Vetter, 1988), where it remains (Babco, 1995).

Studies have found that in high school and particularly during college, women are less likely to continue in MSE fields than are men. For example, female high school students tend to drop out of science classes more often than do male high school students (American Association of University Women, 1992). Furthermore, women in their first and second year of college are less likely to persist in their intention to enroll in science and engineering majors (Carlin, 1997; Carlin & Brainard, 1998) and during their freshman year are more likely to experience a significant drop in their math and science self-concept from which they never fully recover (Brainard, Laurich-McIntyre, & Mobley, 1995).

The poor retention rate of women in MSE majors is reflected in the low number of bachelor degrees awarded to them in MSE fields. For example,

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although women earn approximately 51% of all bachelor's degrees, they earn only 29% of chemistry degrees, 16% of engineering degrees, and 11% of physics degrees (National Science Foundation [NSF], 1994).

The impact of women's underrepresentation in MSE fields may reach well beyond their college years. For example, although women comprise 44% of the workforce, they account for only 8.5% of the engineering professions, 9% of physicists, and 1% of chemists (NSF, 1994). Furthermore, female PhD scientists and engineers are more likely to work at two-year colleges and less likely to be tenured than are male scientists and engineers (NSF, 1999). In the long run, women's lack of experience in MSE fields may limit their access to economic and social power (Burstyn, 1993), particularly in light of society's increasing reliance on technology (NSF, 1994).

What factors might contribute to the high female dropout rate from MSE fields? Some researchers believe that women's low achievement and persistence in MSE are reflections of underlying biological differences between the sexes (Benbow & Stanley, 1980, 1983; Ethington & Wolfle, 1984; Goldman & Hewitt, 1976; Halpern, 1992). According to this viewpoint, men perform better in MSE and persist more in these fields because they possess better spatial–visualization and mathematical reasoning abilities than do women.

However, results from the 1996 National Assessment of Educational Progress (NAEP) mathematics assessment showed that the gender gap in mathematics achievement has, for the most part, diminished (NSF, 1999). Instead of focusing on the purported "hard-wired" sex differences in spatial and reasoning abilities, more researchers are examining the social and psychological mechanisms that may affect women's decision to drop out of MSE. For example, women's lower self-efficacy in math and science may deter them from pursuing nontraditional careers (Hackett & Betz, 1981; Hackett & Campbell, 1987; Lent, Lopez, & Bieschke, 1991; Nevill & Schlecker, 1988; Zimmerman, Bandura, & Martinez-Pons, 1992). Women may also be dropping out of MSE fields because of their lower levels of self-confidence in math and science (Carlin & Brainard, 1998) or because of their tendency to make external attributions for success in math and science and internal attributions for failure in these domains (Dweck & Gilliard, 1975; Hackett & Campbell, 1987).

Gender Stereotypes and Identification With MSE

Past research suggests that gender stereotypes and identification with MSE are important determinants of women's persistence in these fields. In our society, men are reared to be assertive, independent, competitive, and achievement oriented—qualities that give men an edge in the workforce. On the other hand, women are expected to develop stereotypically feminine qualities such as submissiveness, dependence, and cooperation that are ideal for interpersonal relations but not necessarily useful in getting ahead in the work world (Block, 1984). As a result, women's career options may be more restricted than men's because of the emphasis that is placed on women choosing occupations that emphasize their "need to nurture" (Eccles, 1987). In the long run, this pattern of biased socialization may lead to a disproportionate number of women who drop out of MSE fields.

Another example of how stereotypes and identification can differentially affect men's and women's persistence in careers is stereotype threat (Steele, 1997). In the United States there is a well-known stereotype that women are bad at math and science. Researchers have found that activation of this stereotype leads women to feel anxious about disconfirming the stereotype, which ultimately leads them to perform worse on math tests and to have lower expectations about future performances in this domain (Brown & Josephs, 1999; Shih, Pittinsky, & Ambady, 1999; Spencer, Steele, & Quinn, 1999; Stangor, Carr, & Kiang, 1998; Steele, 1997).

Consequently, women who decide to persist in MSE fields may feel uncomfortable and be stigmatized by the salience of the gender stereotype that women are bad at math and science, and that MSE are "male" fields (Dawson-Threat & Huba, 1996). For example, in a study by Yoder and Schleicher (1996), participants wrote an open-ended story about a target person (John or Anne) who was described as being at the top of one of four career fields that have been traditionally gender-skewed (nursing, day care, electrical engineering, or electrician). Participants completed a series of questionnaires that assessed items such as their personal impressions of the target, their desire to get to know and work with him/her, and their overall feelings about the target.

Analysis of the open-ended stories revealed that participants viewed occupational deviance (e.g., Anne as an electrical engineer or as an electrician) as being more costly for women than for men. Specifically, 43% of the open-ended stories written about Anne in nontraditional careers referred to personal and social losses incurred because of educational demands, whereas only 9% of the stories in which John was described as being in a nontraditional career (e.g., nursing, day care) mentioned such losses. Further

support for this biased perception of women versus men in nontraditional careers occurred in the participants' responses to the questionnaires; participants attributed favorable feminine traits to John when he was "occupationally deviant," but derogated Anne when she was in a nontraditional career. In addition, participants rated "nontraditional" Anne as less likeable and attractive, questioned her femininity, socially distanced themselves from her, and evaluated her less positively overall (Yoder and Schleicher, 1996).

Attitude Toward MSE

Women's negative attitudes toward MSE may also be an important factor in understanding why they persist less in MSE fields than do men (Chouinard, Vezeau, Bouffard, & Jenkins, 1999; Eccles, 1987; Holmes, Crossett, & Frostick, 1999; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Nosek, Banaji, & Greenwald, 1998). Two influential conceptualizations of attitude come from the work of Allport (1935) and Thurstone (1931). Allport's definition of attitude establishes a link between attitude and behavior, with attitude being "a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (p. 810). From this definition, researchers inferred that a person's attitude toward an object will guide behavior toward that object by predisposing and energizing the individual to act according to his or her attitude (Pratkanis & Greenwald, 1989). Thurstone provided another conceptualization of attitude as "the affect for or against a psychological object" (p. 261). That is, an attitude is a person's subjective evaluation of an object or thought on a continuum from favorable to unfavorable. Knowledge of a person's attitude toward an object or domain (e.g., MSE fields) may be predictive of his or her intention to engage in a pattern of behaviors toward that object (e.g., persist in these fields).

Explicit Versus Implicit Measures

Although the literature suggests that identification, gender stereotypes, and attitudes toward MSE may ultimately contribute to the disproportionate female attrition rate from MSE fields, these studies relied primarily on explicit measures (e.g., questionnaires, self-reports) to directly measure people's controlled, conscious, and deliberate cognitive processes. The problem with using explicit measures is that they are often tainted by social desirability biases and self-presentational concerns. People may feel pressured to respond as they think they should instead of how they actually think or feel, or may distort their self-reported beliefs and attitudes in order to appear competent, decent, and likeable by others (Brown, 1998; Greenwald, McGhee, & Schwartz, 1998).

In addition, explicit measures may not be very accurate because people are not always aware of their introspective processes; that is, we may not always have access to our attitudes or stereotypes because we can only report what we believe we know or feel. Past research, for example, has shown that people are often unable to report accurately the effects of stimuli on their behavior. A study on altruistic behavior conducted by Latane and Darley (1970, as cited in Nisbett & Wilson, 1977) found that participants continued to claim that their helping behavior had not been influenced by the presence of other people when, in fact, it had been. Similar studies have fueled skepticism among researchers regarding people's ability to accurately introspect about their cognitive processes (Nisbett & Wilson, 1977).

The Implicit Association Test

Because some cognitive processes may be concealed from conscious awareness, it may be necessary to access them in an indirect way (Farnham & Greenwald, 1998; Greenwald & Banaji, 1995; Greenwald et al., 2000, Greenwald et al., 1998). Greenwald et al. (1998) devised an indirect psychological measure, the Implicit Association Test (IAT), that circumvents some of the problems associated with traditional self-report measures by examining identification, stereotypes, and attitudes at a nonconscious, implicit level. The IAT is a computer task that measures the relative speed at which people make automatic associations between target concepts and attributes. The IAT is not, according to Nosek et al. (1998), simply another way to capture the same general attitude or other cognitive process found in explicit measures; rather, the IAT is capable of providing a distinct measure of social cognition.

The IAT assumes that strongly associated concept–attribute pairs (e.g., *flower* and *pleasant)* should be easier to categorize together than weakly associated concept–attribute pairs (e.g., *insect* and *pleasant).* The ease of classifying a concept with an attribute is measured by the response times and errors in performing the categorizations. Participants view a series of words on a computer screen, one at a time, and must categorize each word as quickly as possible by pressing a left or right key on the keyboard. The automatic association between a concept (e.g., *flower)* and an attribute (e.g., *pleasant)* is measured by the difference in speed between the condition in which *flower* and *pleasant* are mapped

together on the same key, and the condition in which *flower* and *unpleasant* are mapped together on the same key.

For example, an IAT measuring implicit identification with MSE would have one condition in which science words (e.g., *scientist, physics)* and self words (e.g., *me, my)* would be paired together on the same key, while art words (e.g., *painter, drama)* and other words (e.g., *them, their)* would be paired together on another key. In the other condition, *self* and *other* would be reversed so that *science* is paired with *other,* and *art,* with *self.* Implicit identification with MSE is determined by taking the difference in response latency times between the two opposing configurations.

Research Overview

Although previous studies have offered a myriad of explanations as to why women are underrepresented in MSE, most of them have relied on explicit measures of data collection (Brainard et al., 1995; Carlin, 1997; Carlin & Brainard, 1998; Dawson-Threat & Huba, 1996). In these studies, participants consciously reflected and then reported on their attitudes, feelings, and beliefs about MSE. However, no implicit measures that could have shed light into people's nonconscious cognitive processes were included with the explicit measures. Implicit measures like the IAT may provide important insights into understanding why women and men have significantly different rates of persistence in MSE. The root of this difference, although not apparent at the explicit, conscious level, might be evident at an implicit, nonconscious level in which people are unfettered by social desirability biases and self-presentational concerns.

The present study focused on three variables that could be measured at both the explicit and implicit level: identification with MSE, gender stereotypes about MSE, and attitude toward MSE. These three factors may be important in understanding why women persist less in MSE fields because they address issues that may be uniquely relevant to being a minority in a nontraditional field. Using the IAT, we examined male and female students' identification with MSE, gender stereotypes about MSE, and attitudes toward MSE. Based on past research, we hypothesized that implicit identification with MSE fields and acceptance of the stereotype that MSE are "male" fields are important determinants of women's intention to major in and persist in MSE. In addition, we sought to confirm that women's implicit associations reflect negative attitudes toward MSE (Nosek et al., 1998).

Method

Participants

Eighty first-year University of Washington students (34 women, 46 men) in MSE Freshmen Interest Groups were recruited to participate during the fall quarter of 1999. Seventy-five students were paid $10 upon completion of the study, and the remaining 5 participants elected to receive optional course credit[1].

Materials

Explicit questionnaires. After filling out a demographic questionnaire (e.g., age, sex), participants completed a questionnaire in which they were asked to indicate their intended major or, if undecided, to rank-order five possible majors. Students also ranked the field of study (arts, English, math, science, or engineering) that they were most likely to pursue in the next 5 years and in the next 10 years.

The identification questionnaires asked participants to indicate how strongly they identified with math, science, engineering, art, and English using a "feeling thermometer" scale (0 = *totally not me;* 100 = *totally me).* The thermometer scale is a visual aid that represents how much a person identifies with an object or domain. Participants also filled out a 7-point semantic differential scale in which they placed an *X* closer to the word (*self* or *other)* that best described how strongly they identified with each field.

On the stereotype questionnaires, participants indicated on a 9-point scale (1 = *strongly disagree;* 9 = *strongly agree)* how much they agreed or disagreed with statements that reflected gender stereotypes about MSE (e.g., "I think that in general, men are better at math, science, and engineering than are women"). Students also completed a 7-point semantic differential scale in which they placed an *X* closer to the word (*male* or *female)* in reference to the fields of math, science, engineering, art, and English.

On the attitude questionnaires, participants indicated on a 9-point scale (1 = *strongly dislike;* 9 = *strongly like)* how much they liked or disliked math, science, engineering, art, and English. Participants also completed a feeling thermometer scale that measured how favorable or unfavorable they felt toward each field (0 = *very cold, unfavorable;* 100 = *very warm, favorable).* Students also filled out a 7-point

[1]The 80 students who participated in the study during the fall quarter (Time 1) were contacted again in the spring of 2000 (Time 2) to return for a follow-up study. The purpose of the follow-up was to assess any changes in implicit and explicit identification, gender stereotypes, and attitudes about MSE over time. Of these 80 students, 72 (31 women, 41 men) returned for the follow-up. The data from the Time 2 sample have yet to be analyzed and reported.

semantic differential scale in which they placed an *X* closer to the adjective (*pleasant* or *unpleasant*) that best described their attitude toward each field.

Implicit measures. Participants completed five IATs on a personal laboratory computer (Microsoft Windows 95 operating system). The MSE, art, and English words that were used in the IATs were generated from mass-testing sessions with introductory psychology students (Cook, 1998). The pleasant and unpleasant words were selected and modified from norms used in previous studies (Bellezza, Greenwald, & Banaji, 1986). In the identification IAT, participants categorized MSE words (e.g., *engineer, algebra*) and art/English words (e.g., *drama, book*) with self versus other words (e.g., *me, them*). In the gender stereotype IAT, participants paired MSE words (e.g., *science, calculus*) and art/English words (e.g., *paint, Shakespeare*) with male versus female words (e.g., *woman, man*). In the attitude IAT, participants categorized engineering words (e.g., *engineer, electrical*) and English words (e.g., *author, book*) with pleasant and unpleasant words (e.g., *happy, filth*). In the second attitude IAT, students categorized math words (e.g., *algebra, calculus*) and art words (e.g., *dance, paint*) with pleasant and unpleasant words. In the third attitude IAT, students categorized science words (e.g., *scientist, chemistry*) with pleasant and unpleasant words.

Procedure

Upon arrival, participants filled out a packet of explicit questionnaires and completed IATs on a computer. The order in which they completed the questionnaires and IATs was counterbalanced. After the participants completed the questionnaires and IATs, they were thanked, debriefed, and paid or given course credit.

Results

Response latencies between 150 and 299 ms were recoded as 300 ms, and latencies between 3,000 and 4,999 ms were recoded as 3,000 ms. Because participants tend to be slower at the beginning of each block, the first two trials of each block were deleted. After performing a logarithmic transformation on the raw latency scores to normalize the distribution, we conducted independent-samples *t* tests between men and women on each IAT.

Identification With MSE IAT

To calculate the IAT effect for implicit identification with MSE, the mean reaction time when MSE was paired with self was subtracted from the mean response time when MSE was paired with other. Higher positive difference scores indicated stronger associations of self to MSE and/or weaker associations to arts. The results of *t*-test analyses showed a significant difference in men's and women's implicit identification with MSE, $t(78) = 2.02$, $p = .05$. Specifically, women associated MSE significantly less with themselves (M [difference] = 18 ms, $SD = 118$) than did men (M [difference] = 68 ms, $SD = 110$).

Gender Stereotypes IAT

The IAT effect for implicit gender stereotypes about MSE was calculated by subtracting the mean reaction time when science was paired with male from the mean reaction time when science was paired with female. Higher positive difference scores indicated stronger acceptance of the stereotype that science is a "male" field and/or art is a "female" field. The results of *t*-test analyses showed a significant difference in men's and women's implicit gender stereotypes about MSE, $t(78) = 2.95$, $p = < .01$. Specifically, the results showed that men had a significantly stronger implicit gender stereotype about MSE (M [difference] = 107 ms, $SD = 104$) than did women (M [difference] = 38 ms, $SD = 98$).

Attitude Toward MSE IAT

The IAT effect for implicit attitude toward engineering was calculated by subtracting the mean reaction time when engineering was paired with pleasant from the mean response time when engineering was paired with unpleasant. Higher positive difference scores indicated more positive associations to engineering and/or more negative associations to English. The results of *t*-test analyses showed that the sex difference in implicit attitudes toward engineering approached significance, $t(78) = 1.87$, $p = .06$, with women showing slightly more negative implicit attitudes toward engineering (M [difference] = −31 ms, $SD = 100$) than men (M [difference] = 11 ms, $SD = 114$).

The IAT effect for implicit attitude toward math was calculated by subtracting the mean reaction time when math was paired with pleasant from the mean response time when math was paired with unpleasant. Higher positive difference scores indicated more positive associations to math and/or more negative associations to arts. The results of *t*-test analyses showed that there was no significant difference in men's and women's implicit attitudes toward math, $t(78) = .18$, $p = .86$. However, the trend was in the anticipated direction, with women showing slightly more negative implicit attitudes toward math (M [difference] = −8 ms, $SD = 119$) than men (M [difference] = −11 ms, $SD = 115$).

Lastly, the IAT effect for implicit attitude toward science was calculated by subtracting the mean reac-

tion time when science was paired with pleasant from the mean response time when science was paired with unpleasant. Higher positive difference scores indicated more positive associations to science and/or more negative associations to arts. The results of *t*-test analyses revealed that there was no significant difference between men's and women's implicit attitudes toward science, $t(78) = -.59$, $p = .55$. In other words, women did not show more negative implicit attitudes toward science (M [difference] = −27 ms, $SD = 111$) than did men (M (difference) = −45 ms, $SD = 135$).

Explicit and Implicit Correlations

Identification with MSE. Scores from the semantic differential and feeling thermometer scales were weighted and combined to create an aggregate "identification with MSE" score. There were no significant correlations between explicit and implicit measures for men, $r = .25$, $p = .09$, nor for women, $r = .30$, $p = .08$.

Gender stereotypes. The aggregate score for stereotyped views about gender and science was calculated by averaging participants' responses on the seven-question stereotype questionnaire. For men, the explicit–implicit stereotype correlation was not significantly correlated, $r = .11$, $p = .47$. For women, the correlation was also not significantly correlated, $r = -.20$, $p = .26$. Furthermore, correlating the stereotype semantic differential scale with the stereotype IAT revealed no significant correlations for men, $r = .12$, $p = .43$, nor for women, $r = -.01$, $p = .96$.

Attitude toward MSE. The aggregate score for the explicit measures of attitude was calculated by weighting and combining the scores on the semantic differential scale and feeling thermometers for attitude toward MSE. The correlation between explicit and implicit measures of attitude toward MSE was not significantly correlated for men, $r = .02$, $p = .92$. For women, there was a significant correlation between their explicit–implicit attitude toward MSE, $r = .39$, $p = .02$. In other words, there was a higher correspondence between women's explicit, self-reported attitudes toward MSE and their implicit, nonconscious attitudes toward MSE. This finding suggests that women may have been more accurate than men in self-reporting their attitudes toward MSE.

Discussion

The aim of the present study was to determine what factors might affect women's decision to drop out of MSE fields at a higher rate than men. In particular, the focus of the study was to observe whether there were significant differences between men and women on implicit measures of identification with MSE, stereotypes about gender and MSE, and attitudes toward MSE. Another goal of the study was to determine whether the explicit and implicit measures of these variables were correlated.

Contrary to Nosek et al.'s (1998) findings, the present study found that overall, men and women did not differ significantly in their implicit attitudes toward MSE. These results suggest that attitude may not be the primary reason that women drop out of MSE fields at a disproportionate rate. Rather, the results reveal that identification with MSE may be one of the key factors that influences one's decision to persist in MSE fields. In the present study, we found that men more strongly associated MSE with themselves than did women, which is not surprising considering that many women in male-dominated science and engineering programs often report feeling alienated (Brainard et al., 1995). The findings are also consistent with Carlin's (1997) longitudinal study of first-year college students in MSE programs. Carlin found that freshmen students' science self-concepts were better predictors of long-term persistence in MSE than were their science GPAs or changes in MSE self-efficacy. In addition, Brainard et al.'s (1995) 6-year longitudinal study of college women in science and engineering showed that students' MSE self-concepts were consistent predictors of whether or not they persisted in MSE or switched to another field.

Another factor that may deter women from committing to MSE is their implicit acceptance of the stereotype that MSE are "male" fields. In the present study, men showed significantly stronger gender stereotypes about MSE than did women. This finding raises the question of whether women are dropping out of MSE fields at a higher rate than are men, or whether men, as evidenced by their stronger gender stereotype, are choosing to stay in these fields at a higher rate than are women. Future research could extend the current findings and address such a question. In terms of the present study, women, as minorities in a predominantly male field (i.e., MSE), may experience increased gender role conflict that may affect their subsequent persistence or attrition from MSE fields (Luhaorg & Zivian, 1995). Indeed, Yoder and Schleicher (1996) supported this idea by showing that an "occupationally deviant" woman (e.g., Anne the electrical engineer) was stigmatized to a greater extent than was a man in a nontraditional career (e.g., John the nurse). With such negative, pervasive stereotypes, it is not surprising that many women decide not to persist in MSE fields.

Furthermore, because our explicit–implicit measures of identification and stereotype did not highly

correlate, the present results support Nosek et al.'s (1998) position that implicit measures provide important and unique information. According to Nosek et al., implicit measures may be better predictors of behavioral intention and behavior than explicit measures. Because men and women in our sample differed significantly in their implicit identification with MSE, this factor may be predictive of women's decision to persist, or not, in MSE. Women's implicit acceptance of the stereotype that MSE are "male" fields may also predict persistence, or lack thereof, among women. By using implicit measures, we can circumvent social desirability biases and provide deeper insights into the underlying cognitive processes that affect behavior.

Ultimately, the question of what leads women to persist or drop out of MSE fields is an issue that warrants further investigation as it will affect society in the long run. An application of the present findings is to support MSE initiatives and other mentoring programs that are aimed at retaining women in MSE. These programs provide women with the academic tools, role models, and supportive climate they need to build a stronger basis of identification with MSE and to help dispel the stereotype that MSE are "male" fields.

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