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# “I think I can, but I'm afraid to try”: The role of self-efficacy beliefs and mathematics anxiety in mathematics problem-solving efficiency

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ABSTRACT

This study investigated the role of self-efficacy beliefs, mathematics anxiety, and working memory capacity in problem-solving accuracy, response time, and efficiency (the ratio of problem-solving accuracy to response time). Pre-service teachers completed a mathematics anxiety inventory measuring cognitive and affective dispositions for mathematics, before completing an operation span task to measure working memory capacity, rating self-efficacy for mental multiplication, and then solved computer-based multiplication problems at two complexity levels. A simultaneous regression design was used to assess the unique variance associated with each variable. There were two new findings; the differential role of self-efficacy on response time and efficiency, and the potential compensatory relationship between self-efficacy and mathematics anxiety related to efficiency outcomes. Educational implications and suggestions for future research were proposed.



Mathematics anxiety, the state of nervousness and discomfort brought upon by the presentation of mathematical problems, may impede mathematics performance irrespective of true ability (Aiken, 1970; Ashcraft, 2002, 2005; Ashcraft & Moore, 2009; Suinn & Edwards, 1982). Over the past thirty years, studies have shown mathematics anxiety is a highly prevalent problem for students (Baloglu & Koçak, 2006; Betz, 1978; Jain & Dowson, 2009; Ma & Xu, 2004; Rodarte-Luna & Sherry, 2008) and especially for pre-service teachers (Brady & Bowd, 2005; Gresham, 2007, 2008). The impact is pervasive as both pre- and in-service teachers reported their own mathematics anxiety is a major concern (Bursal & Paznokas, 2006), and future teachers are more maligned than their non-academic peers. Mathematics anxiety in teachers is related to pedagogical practice and perpetuates a lack of student confidence in their own mathematics abilities (Steele, 1997). For students, perhaps the greatest impact of mathematics anxiety relates to performance, as a strong negative correlation exists between mathematics anxiety and mathematics achievement (Ashcraft, 2002; Ashcraft & Kirk, 2001; Bandalos, Yates, & Thorndike-Christ, 1995; Cates & Rhymer, 2003; Ma & Xu, 2004; Miller & Bichsel, 2004).

Self-efficacy, the belief in one's ability to execute courses of action to achieve desired results (Bandura, 1986), is related to superior performance and may moderate the influence of anxiety on mathematics (Hackett, 1985; Jain & Dowson, 2009; Pajares, 1996; Pajares & Graham, 1999; Pajares & Kranzler, 1995; Pajares & Miller, 1994; Shores & Shannon, 2007). Meta-analytic evidence reveals a weighted average correlation between self-efficacy and performance of .38 (Stajkovic & Luthans, 1998). This moderate positive relationship closely approximates the magnitude of the average correlation between anxiety and mathematics performance (-.27 to -.39), although in the opposite direction (Hembree, 1990; Lee, 2009; Ma, 1999).

Some research has been conducted on the relationship among mathematics anxiety, self-efficacy, and performance (Cooper & Robinson, 1991; Kesici & Erdoğan, 2009; Lee, 2009); however, little if any, research has been conducted on the role of self-efficacy and mathematics anxiety on problem-solving *efficiency*, the ratio of accuracy to time (Hoffman & Spatariu, 2008, Hoffman & Schraw, 2009, 2010; Mory, 1992). Efficiency outcomes are important due to the current emphasis on educational productivity (López, 2007; Valli & Buese, 2007), and the growing trend in educational research that investigates not only performance outcomes related to learning, but also the rate and amount of time or effort needed to attain knowledge (Hoffman & Schraw, 2010; Corbalan, Kester, & van Merriënboer, 2008; Pyc & Rawson, 2007).

Accordingly, the goal of the present research was to answer two specific research questions. First, what is the role, if any, of self-efficacy beliefs and mathematics anxiety in efficiency outcomes and second, does the impact of these variables differ contingent upon level of problem complexity and working memory capacity (WMC), defined as the elements activated in memory needed to store and process information, and an integral part of mathematics problem-solving success (Engle, Tuholski, & Laughlin, 1999; Raghubar, Barnes, & Hecht, 2010; Seitz & Schumann-Hengsteler, 2000).

## 1. Mathematics anxiety

Anxiety encountered by students and teachers is typically triggered by circumstances perceived as threatening, such as

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unfamiliar problems, problems deemed overly complex, or the perception of negative attitudes and expectations (Onwuegbuzie & Wilson, 2003). For example, students accustomed to solving problems without time restrictions might develop anxiety if told they need to solve problems quickly (Ashcraft & Moore, 2009). Origins of mathematics anxiety differ broadly, but are frequently linked to lower ability perceptions (Rounds & Hendel, 1980), prior unsuccessful experience (Ma & Xu, 2004; Zeidner, 1991), maladaptive attributions (Bandalos et al., 1995), lack of study and test preparation skills (Spielberger & Vagg, 1995), and situational affective factors (Hong & Karstensson, 2002; Sorg & Whitney, 1992) such as the perception of autonomic and somatic arousal, or increased worry.

Teachers and students with high mathematics anxiety, irrespective of ability, perceive they are less competent than individuals with lower mathematics anxiety (Ashcraft & Moore, 2009). Self-perceptions may result in lower achievement outcomes and a predetermined attitude towards mathematics which can influence dispositions towards learning (Ferla, Valcke & Cai, 2009; Peterson, Fennema, Carpenter, & Loef, 1989). For example, Meece, Wigfield, and Eccles (1990) used structural equation modeling to test the relations among grades, perceptions of mathematics ability, and performance and value perceptions on mathematics anxiety. Performance expectations had the strongest direct effects on anxiety leading to the conclusion that "students' interpretations of outcomes, not the outcomes themselves have the strongest effects on affective reactions" (p. 68).

## 2. Working memory

Simple competence models explaining mathematics anxiety are incomplete and exclude the role of WMC. The relationship between WMC, the ability to process and store information in consciousness, and mathematics performance is ubiquitous (Hoffman & Schraw, 2009; DeStefano & LeFevre, 2004; Hecht, 2002; Raghubar et al., 2010) with WMC explaining as much as 30% of the unique variance in mathematics performance above and beyond mathematics ability. Ashcraft and colleagues (Ashcraft, 2005; Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Ashcraft & Moore, 2009) have consistently shown mathematics anxiety is only partially tied to actual domain competence, and working memory ability discounts mathematics knowledge as a complete explanation of mathematics performance.

The divergent focus of cognitive resources is often offered as an explanation for accuracy reductions related to mathematics anxiety. Consistent with processing efficiency theory (Eysenck & Calvo, 1992), the uncomfortable feelings and worry associated with mathematics anxiety facilitates an intellectual paralysis, usurping precious working memory resources, and diverting attention which might otherwise be directed to task processing. The emotional implications of the intrusive thoughts related to worry interferes with task focus, and potentially may result in performance apathy and task avoidance motivation due to the anticipation of aversive task consequences (Eysenck & Calvo, 1992), and a potential negative intrusion upon the individual's self-perceptions of competence.

## 3. Problem-solving efficiency

The impact of mathematics anxiety upon problem-solving *efficiency*, the ratio of problem-solving accuracy to problem-solving time (Hoffman & Schraw, 2010), is less clear. Similar to problem-solving accuracy, the ability to perform efficiently is also influenced, in part, by available working memory resources (DeStefano & LeFevre, 2004; Heitz, Unsworth, & Engle, 2005; Walczyk, 2000). Greater efficiency is probable when individuals have more capacity and dedicated cognitive resources targeted toward task demands. The diverted attention endemic to high anxious individuals, regardless of ability, strains working memory resources. As a consequence, a response to a problem is abated, resulting in longer problem-solving times and lower efficiency (Hoffman & Schraw, 2009; Eysenck & Calvo, 1992).

Efficiency is related to the judicious use of strategies. Students may use "compensations" (Walczyk & Griffith-Ross, 2006, p. 618) to "overcome deficits of various kinds" (Walczyk, 2000, p. 560) without sacrificing accuracy (Walczyk & Griffith-Ross, 2006; Walczyk, Wei, Griffith-Ross, Goubert, Cooper, & Zha, 2007) and the use of certain problem-solving strategies mediates anxiety (Jain & Dowson, 2009). For example, Walczyk and Griffith-Ross (2006) examined the efficiency of solving algebraic inequality problems under both timed and untimed conditions and found that students used strategies such as pausing, looking back, and reading aloud to maintain accuracy. Students under the perception of limited pressure were able to compensate for working memory limitations, although at the expense of problem-solving efficiency due to longer problem-solving times.

In contrast, some researchers (Ashcraft & Krause, 2007; Humphreys & Revelle, 1984; Faust, Ashcraft, & Fleck, 1996) suggest that high-anxious individuals may actually have *faster* problem-solving times. Students solving problems which evoke feelings of discomfort or worry may want to finish the task as soon as possible (Faust et al., 1996) resulting in quicker completion of problems, although potentially at the expense of accuracy. Thus, a conundrum exists, as a significant finding for WMC on efficiency would suggest faster problem solving times and support previous research (Ashcraft & Kirk, 2001; Ashcraft, 2002; Ashcraft & Krause, 2007), yet discount some assumptions of processing efficiency theory (Eysenck & Calvo, 1992) that contends allocating additional resources (i.e. effort) and/or initiating processing activities (i.e. strategies) impairs performance efficiency due to longer problem-solving time.

## 4. Mathematics anxiety and gender

Studies concerning the relationship between gender and mathematics anxiety show ambiguous results (Anglin, Pirson, & Langer, 2008; Hall, Davis, Bolen, & Chia, 1999; Meelissen & Luyten, 2008; Penner & Paret, 2008). Some studies report women have higher mathematics anxiety than men and as a result are less likely to seek mathematical problem-solving opportunities, mathematics careers, and tend to avoid activities related to mathematics such as computers and technology (Baloglu & Koçak, 2006; Bandalos et al., 1995; Betz, 1978). In contrast, Hembree's meta-analysis (1990) indicated the negative behaviors associated with mathematics anxiety were more pronounced in high school males than females, while Miller and Bichsel (2004) found mathematics anxiety had a stronger influence on the performance of males when solving problems of basic calculation than females. Frequently, studies across populations and cultures find minimal advantage for males' mathematics performance with small effect sizes (Hyde et al., 1990), and gender differences in mathematics performance can be explained by differences in levels of mathematics anxiety (Osborne, 2001). Recent findings (Frenzel, Pekrun, & Goetz, 2007) indicated that the achievement disparity in mathematics is "small and declining" (p. 498) with competence beliefs a stronger driver of performance outcomes.

## 5. Self-efficacy

Individuals with higher levels of self-efficacy are more effortful, attempt more cognitively challenging problems, persist longer, and use productive problem-solving strategies (Pajares, 1996; Pajares & Graham, 1999; Pajares & Kranzler, 1995). Self-efficacy has a negative relationship with mathematics anxiety (Bandalos et al., 1995; Cooper & Robinson, 1991; Jain & Dowson, 2009; Ma & Xu, 2004; Meece et al., 1990) and has been shown to mediate the role of gender on mathematics problem-solving performance (Pajares & Miller, 1994). The self-efficacy beliefs of teachers with mathematics anxiety are especially critical as teacher beliefs influence the perceptions of mathematics by their students (Steele, 1997). One recent study indicated, "Nearly half of the pre-service teachers having higher mathematics anxieties than their colleagues believe that they will not be able to teach mathematics effectively" (Bursal & Paznokas, 2006, p. 177). Another study found mathematics anxiety negatively correlated with teacher efficacy and indicated, "Mathematics teachers pass their anxiety on to their students" (Brady & Bowd, 2005, p. 44). Indeed, research frequently emphasizes the strong role of teacher beliefs as being one of the most influential factors determining teacher effectiveness (Woolfolk Hoy, Davis, & Pape, 2006).

Despite the prevalence of the mediating effects of self-efficacy, adaptive beliefs alone are not a magical remedy to augment problem-solving accuracy. Limitations prevail when solving highly complex problems (Lane & Lane, 2001), and when problems are overly familiar. Enhanced self-efficacy can be problematic as motivation and effort may be withheld due to the expectation of easily achieving success (Vancouver & Kendall, 2006). Additionally, the calibration accuracy of an individual's self-efficacy beliefs is instrumental in successful performance outcomes (Chen, 2002). If task difficulty is underestimated and anticipated outcomes are not commensurate with results, self-efficacy may regress (Bandura, 1997). Stajkovic and Luthans (1998), in a meta-analysis of the effects of self-efficacy on work performance, reported the role of self-efficacy diminished as task complexity increased. Thus, it is unknown if the relationship between self-efficacy and mathematics anxiety will be sustained as problem complexity increases, which is precisely the usual circumstance when mathematics anxiety is heightened (Ashcraft, 2002).

## 6. Present study

The present study used a simultaneous regression design to determine the unique variance attributed to self-efficacy, mathematics anxiety, WMC, and gender when solving problems of mental multiplication. In addition, the impact of these variables was investigated as a function of problem complexity. Mental multiplication at two complexity levels was used because students are familiar with these types of problems (LeFevre, Bisanz, Daley, Buffone, Greenham, & Sadesky, 1996; Mabbott & Bisanz, 2003; Siegler, 1988), and problems of escalating complexity place increasing demands on WMC (Campbell & Xue, 2001), which has been found to explain variance in problem solving above and beyond mathematics ability (DeStefano & LeFevre, 2004; Seitz & Schumann-Hengsteler, 2000; Swanson & Beebe-Frankenberger, 2004).

Added support was expected for the *motivational efficiency hypothesis* (Hoffman & Spatariu, 2008; Hoffman & Schraw, 2009), which suggests that motivational beliefs such as self-efficacy, and strategy attributions are related to enhanced accuracy and faster problem-solving times. Minimal gender differences related to self-efficacy and problem-solving accuracy and efficiency were anticipated consistent with the extant literature (Hembree, 1990; Hyde et al., 1990) Last, it was expected as problem complexity increased participants with higher mathematics anxiety and lower self-efficacy would show a decrease in problem-solving accuracy and problem-solving efficiency.

## 7. Method

### 7.1. Participants

Participants were volunteer pre-service teachers from two universities (N = 70) who received extra course credit for their involvement. The reason for multiple settings was convenience motivated to enhance sample size. Thirty-nine students (M = 9, F = 30, mean GPA 3.39) were undergraduates enrolled in educational psychology courses at a large southwestern university with a minority population of 9% African American, 18% Asian, and 14% Hispanic, and 31 were graduate students (M = 10, F = 21, mean GPA 3.73) enrolled in education courses at a large southeastern university with a minority population of 9% African American, 5% Asian, and 14% Hispanic. All participants were pre-service teacher candidates either in traditional or alternative certification programs.

### 7.2. Measures

The Mathematics Anxiety Scale (MAS, Betz, 1978; Fennema & Sherman, 1976), a Likert-type survey (1 = extremely uncharacteristic; 5 = extremely characteristic) measured the extent of mathematics anxiety in participants. The MAS consisted of ten items, equally divided between positive and negative statements concerning attitudes and experiences encountered in the selection, use, and completion of mathematics and mathematics-related tasks, and included items such as, "I get nervous before mathematics tests," and "My mind goes blank and I am unable to think clearly when doing mathematics." The MAS has been used extensively at the college, high school, and middle school levels with split-half reliability of .92 (for factor structure, see Pajares & Urdan, 1996). The instrument was especially suited to the present study as factor loadings suggested the main measurement construct is worry, the component of anxiety which has been shown to be offset by perceptions of self-efficacy (Bandalos et al., 1995).

WMC was measured with an operation span task (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005) that required participants to solve problems while concurrently remembering words. Participants saw a simple numerical equation and a solution to the equation followed by a word. The problems involved single-digit multiplication or division (for example $6/3 + 2 = 5$). The task required participants to determine if the solution indicated for the problem was correct or incorrect. Computational accuracy of 85% or greater was necessary for results to be included in the study. The goal of the task was to remember the words following the problems and to recall the words in the exact presentation order. Students had several practice trials to get used to the process. No time limits were involved. Each word recalled in exact serial order received one unit of scoring credit. The total number of words recalled and correctly transcribed was the criterion measure to determine WMC. The operation span task is widely validated as a measure of WMC (Conway et al., 2005) and was not used to measure basic mathematics ability.

Self-efficacy for mental multiplication was measured by participants' self-reported confidence in solving eight different multiplication problems, identical in length and difficulty to items solved in the actual study, although the exact digits differed. This method of measuring self-efficacy was equivalent to Lopez, Lent, Brown, and Gore (1997). Students rated problems on an eleven-point scale ranging from no confidence at all in solving (0%), to total confidence in solving (100%) under the expectation of solving the problems both accurately and as quickly as possible without making mistakes. Participant's self-efficacy ratings were averaged to determine an overall rating of self-efficacy for solving mental multiplication.

Finally, for the criterial task, each participant, without the use of calculation aids, mentally solved ($20_{easy}$) 2-digit × 1-digit problems with three digit solutions (e.g. $49 \times 9 = 441$) and ($20_{hard}$) 2-digit × 2-digit problems with three digit solutions (e.g. $45 \times 12 = 540$). As the number of digits in the problems increased the problem was considered to be of greater complexity due to the well documented problem size effect (Ashcraft, 1992; Campbell & Xue, 2001). Participants were not given time restrictions but were instructed to answer each problem "as quickly and as accurately as possible without making mistakes". This method and the types of problems used were identical to other highly reliable studies (see Hoffman & Spatariu, 2008; Hoffman & Schraw, 2009 for a complete description of problem construction and methodology).

### 7.3. Procedures

All measures were administered in the order described to students individually in a small, private, windowless room to control for differences across locations. Each measure was prefaced by both written and scripted verbal instructions, which were identical across study locations. After the completion of the series of tasks, each participant received a short scripted debriefing explaining the purpose of the study. No item level feedback was provided to the participants.

The total number of problems answered correctly, at each complexity level, determined problem-solving accuracy. Problem-solving time was determined by the latency of response for each of the 40 problems, recorded in milliseconds, and converted to seconds for ease of analysis. Problem-solving efficiency was determined by computing the ratio between the numbers of problems solved accurately and problem-solving time for each of the 40 problems of mental multiplication. The ratio of problem-solving accuracy to problem-solving time was multiplied by 1000 for ease of comparison. Reliability coefficients using Cronbach's alpha were calculated to determine the reliability of each self-report measure. Results indicated the measures were highly reliable, self-efficacy $\alpha = .958$ and mathematics anxiety $\alpha = .932$.

## 8. Results

A simultaneous multiple regression was performed for each dependent variable (accuracy, response time, and efficiency) at each level of complexity (labeled easy, hard) with self-efficacy, WMC, and mathematics anxiety as the predictor variables. The analysis was performed using SPSS 15.0 for Windows. Results were screened for violation of assumptions and outliers, resulting in two cases being removed from the statistical analysis due to excessive problem-solving time. Based upon the research hypothesis, an interaction term was created between the predictors' self-efficacy and WMC, and tested separately. Mean centering was used to control for multicollinearity. A separate regression model was created excluding the interaction term from the model and tested separately when the interaction term was not significant (Aiken & West, 1991).

*T*-tests were conducted to determine if results were influenced by gender, location, or level of education. Gender differences for problem-solving accuracy and efficiency for the more complex problems were found, $t_{(68)} = 2.99$, $p = .005$, males answered more problems correctly (M = 12.26, SD = 4.95), than females (M = 7.88, SD = 5.61). Additionally, males were more efficient $t_{(68)} = 3.24$, $p = .002$, (M = 16.83 SD = 9.71), than females (M = 9.65 SD = 7.66). Significant gender differences were also observed for the self-efficacy assessment, $t_{(68)} = 2.41$, $p < .05$, males had higher self-efficacy (M = 80.72, SD = 15.96) than females (M = 66.42 SD = 23.96). No other significant differences were observed.

### 8.1. Descriptive statistics and correlations

Means and standard deviations for each measure and are presented in Table 1. Zero-order correlations are presented in Table 2. The correlation table revealed a significant positive relationship between the self-efficacy variable and WMC. Additionally, a positive relationship between self-efficacy and problem-solving accuracy and problem-solving efficiency was found. Strong relationships were observed among the problem-solving accuracy and problem-solving efficiency outcome variables. Significant negative relationships between mathematics anxiety and self-efficacy were observed. A regressive relationship between mathematics anxiety and self-efficacy was observed (see Fig. 1), although the variables were negatively correlated, as students solved more problems correctly, the influence of mathematics anxiety and self-efficacy decreased.

No significant interactions between the self-efficacy variable and WMC were observed therefore in each analysis the interaction term was removed from the regression equation in order to obtain an estimate of the unique variation explained by each variable. Complete results of the multiple regression analysis by predictor and complexity level can be seen in Table 3.

**Table 1**
Descriptive statistics.

| Variable | Mean | SD | Observed range | Possible range |
|---|---|---|---|---|
| Accuracy (number correct) | | | | |
| Easy | 16.37 | 3.97 | 3.00-20.00 | .00 - 20.00 |
| Hard | 9.07 | 5.75 | .00-19 | .00 - 20.00 |
| Response Time (milliseconds/1000) | | | | |
| Easy | 353.08 | 124.96 | 175.50-806.03 | .001- ∞ |
| Hard | 821.62 | 268.91 | 228.87-1595.10 | .001- ∞ |
| Efficiency (accuracy/time × 1000) | | | | |
| Easy | 52.21 | 20.37 | 3.72-96.86 | .001- ∞ |
| Hard | 11.59 | 8.80 | .00-36.32 | .001- ∞ |
| Self-efficacy | 70.30 | 22.88 | 17.50-100.00 | .00 - 100.00 |
| WMC | 31.36 | 5.40 | 18.00-42.00 | .00 - 42.00 |
| Math Anxiety | 2.68 | 1.15 | 1.00-5.00 | 10.00 - 50.00 |

### 8.2. Problem-solving accuracy

The regression of problem-solving accuracy on self-efficacy, WMC, and mathematics anxiety were statistically significant, $F\ (3, 66) = 5.60$, $MSR = 12.27$, $p < .001$, $R^2 = .270$. Self-efficacy was a statistically significant predictor of problem-solving accuracy, $\beta = .31$, $t = 2.42$, $p = .018$. Squared semipartial correlations revealed that 6.6% of the variation in problem-solving accuracy was accounted for by self-efficacy.

At the second level of complexity, the overall model was significant, $F\ (3, 66) = 8.30$, $MSR = 23.29$, $p < .001$, $R^2 = .34$. Individually, WMC and mathematics anxiety were both predictive of problem-solving accuracy, respectively, $\beta = .35$, $t = 3.18$, $p = .002$, and $\beta = -.29$, $t = -2.12$, $p = .038$. Squared semipartial correlations revealed that 10.3% of the variation in problem-solving accuracy was accounted for by WMC and 5.29% by mathematics anxiety. No other significant findings were observed for accuracy.

### 8.3. Problem-solving time

At the first level of complexity, the regression of problem-solving time on self-efficacy, WMC, and mathematics anxiety were statistically significant, $F\ (3, 66) = 3.67$, $MSR = 13{,}522.29$, $p = .009$, $R^2 = .18$. Self-efficacy predicted problem-solving time, $\beta = -.35$, $t = -2.58$, $p = .012$. Squared semipartial correlations revealed that 8.35% of the variation in problem-solving time was accounted for by self-efficacy. No other significant findings were observed for time.

### 8.4. Problem-solving efficiency

The regression of problem-solving efficiency on self-efficacy, WMC, and mathematics anxiety was statistically significant, $F\ (3, 66) = 7.10$, $MSR = 306.74$, $p < .001$, $R^2 = .30$. Self-efficacy predicted problem-solving efficiency, $\beta = .39$, $t = 3.17$, $p = .002$. Squared semipartial correlations revealed 10.7% of the variation in problem-solving efficiency was accounted for by self-efficacy.

Similar results were observed at the second level of problem complexity, as the regression of problem-solving efficiency on self-efficacy, WMC, and mathematics anxiety, revealed statistical significance, $F\ (3,66) = 7.28$, $MSR = 56.83$, $p < .001$, $R^2 = .31$. WMC predicted problem-solving efficiency, $\beta = .33$, $t = 2.95$, $p < .005$ accounting for 9.24% of the variation in problem-solving efficiency. Additionally, self-efficacy, although not a significant predictor of problem-solving efficiency, $\beta = .23$, $t = 1.87$, $p < .07$, was in the direction of significance, accounting for 3.6% of the variation in problem-solving efficiency. No other significant findings were observed for efficiency.

**Table 2**
Correlations.

| Study Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. GPA | _ | .02 | .29* | -.05 | .26* | .22 | -.07 | .21 | .21 | .16 |
| 2. Self-efficacy | | - | .35** | -.48** | .46** | .42** | -.39** | .01 | .49** | .42** |
| 3. Working memory | | | - | -.23 | .33** | .46** | -.15 | .03 | .36** | .45** |
| 4. Math anxiety | | | | - | -.38** | -.42** | .30* | .01 | -.33** | -.36** |
| 5. Accuracy easy | | | | | - | .56** | -.39** | .28* | .66** | .41** |
| 6. Accuracy hard | | | | | | - | -.25* | .20 | .48** | .88** |
| 7. Time easy | | | | | | | - | .33** | -.82** | -.37** |
| 8. Time hard | | | | | | | | - | -.10 | -.20 |
| 9. Efficiency easy | | | | | | | | | - | .54** |
| 10. Efficiency hard | | | | | | | | | | - |

**Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

## 9. Discussion

The main objective of the present study was to determine the relationship of mathematics anxiety and self-efficacy in the mathematics problem-solving efficiency of pre-service teachers during dual-level unrestricted conditions when controlling for WMC and gender. The results supported the motivational efficiency hypothesis; as self-efficacy was related to both problem-solving accuracy and problem-solving efficiency. Additionally, as predicted, for more complex problems, mathematics anxiety and WMC were related to accuracy. The results supported previous findings, which indicated self-efficacy (Cooper & Robinson, 1991; Pajares, 1996; Pajares & Graham, 1999), anxiety (Eysenck & Calvo, 1992; Hembree, 1990; Miller & Bichsel, 2004; Shores & Shannon, 2007) and WMC (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Bandalos et al., 1995) play a decisive role in mathematics problem-solving accuracy.

The present study suggests at least two new findings: the role of self-efficacy on mathematics problem-solving efficiency due to time effects, and the potential compensatory relationship between self-efficacy and mathematics anxiety on efficiency outcomes. Self-efficacy was a significant predictor of problem-solving efficiency for less complex problems as evidenced by greater accuracy *and* reduced problem-solving time. This finding corroborates the role of self-perceptions influencing anxiety reduction (Lee, 2009) and the use of compensatory strategies found by other researchers (Jain & Dowson, 2009; Walczyk et al., 2007; Walczyk & Griffith-Ross, 2006), but raises new questions as to how self-efficacy acts as a mediator of problem-solving efficiency. The evidence represented by Fig. 1 used standardized scores and shows a regressive relationship between mathematics anxiety and self-efficacy for lower complexity problems. Although the overall correlation between mathematics anxiety and self-efficacy was -.46, as the number of problems solved correctly increased, both

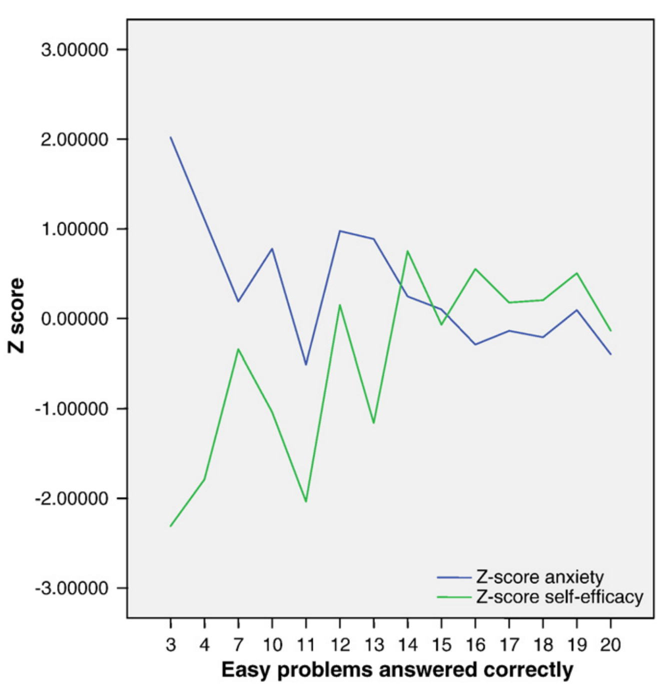


**Fig. 1.** Easy problems answered correctly as a function of standardized anxiety scores and self-efficacy ratings.

**Table 3**
Results of multiple regression analysis by predictor and complexity level.

| Predictor variable | $\beta$ | SE | T | p | F | df | p | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Accuracy-easy | | | | | | | | |
| Model with interaction | | | | | 5.26 | 4, 65 | <.001 | .29 |
| Self-efficacy × WMC* | -.16 | .01 | -1.39 | .169 | | | | |
| Model w/o interaction | | | | | 5.60 | 3, 66 | <.001 | .27 |
| Self-efficacy | .31 | .02 | 2.42 | .018 | | | | |
| WMC | .18 | .09 | 1.54 | .130 | | | | |
| Anxiety | -.19 | .43 | -1.51 | .136 | | | | |
| Accuracy-hard | | | | | | | | |
| Model with interaction | | | | | 6.67 | 4, 65 | <.001 | .34 |
| Self-efficacy × WMC* | -.07 | .01 | -.65 | .521 | | | | |
| Model w/o interaction | | | | | 8.30 | 3, 66 | <.001 | .34 |
| Self-efficacy | .17 | .03 | 1.40 | .167 | | | | |
| WMC | .35 | .12 | 3.18 | .002 | | | | |
| Anxiety | -.29 | .59 | -2.12 | .038 | | | | |
| Time-easy | | | | | | | | |
| Model with interaction | | | | | 3.18 | 4, 65 | .013 | .20 |
| Self-efficacy × WMC* | -.13 | .117 | -1.07 | .287 | | | | |
| Model w/o interaction | | | | | 3.67 | 3, 66 | .009 | .18 |
| Self-efficacy | -.35 | .74 | -2.58 | .012 | | | | |
| WMC | .01 | 2.79 | .10 | .918 | | | | |
| Anxiety | .17 | 14.18 | 1.30 | .199 | | | | |
| Time-hard | | | | | | | | |
| Model with interaction | | | | | .89 | 4, 65 | .494 | .07 |
| Self-efficacy × WMC* | -.15 | .27 | -1.18 | .243 | | | | |
| Model w/o interaction | | | | | .76 | 3, 66 | .555 | .05 |
| Self-efficacy | -.03 | 1.72 | -.20 | .841 | | | | |
| WMC | .05 | 6.49 | .38 | .705 | | | | |
| Anxiety | .07 | 33.02 | .48 | .632 | | | | |
| Efficiency-easy | | | | | | | | |
| Model with interaction | | | | | 5.61 | 4, 65 | <.001 | .31 |
| Self-efficacy × WMC* | -.03 | .02 | -.29 | .771 | | | | |
| Model w/o interaction | | | | | 7.10 | 3, 66 | <.001 | .30 |
| Self-efficacy | .39 | .11 | 3.17 | .002 | | | | |
| WMC | .19 | .42 | 1.72 | .090 | | | | |
| Anxiety | -.13 | 2.14 | -1.10 | .278 | | | | |
| Efficiency-hard | | | | | | | | |
| Model with interaction | | | | | 5.73 | 4, 65 | <.001 | .31 |
| Self-efficacy × WMC* | .01 | .01 | .01 | .999 | | | | |
| Model w/o interaction | | | | | 7.28 | 3, 66 | <.001 | .31 |
| Self-efficacy | .23 | .05 | 1.87 | .066 | | | | |
| WMC | .33 | .18 | 2.95 | .004 | | | | |
| Anxiety | -.12 | .92 | -1.60 | .115 | | | | |

* $\beta$ reflect use of centered means.

the relative influence of mathematics anxiety and self-efficacy was diminished.

Anxiety developed as problems became more complex, suggesting that self-efficacy was a prevailing variable that compensated for anxiety when problems were perceived as easier. Apparently, once the threshold of complexity exceeded the individual's level of perceived competence or ability, students may not have accurately predicted problem-solving success (Chen, 2002), no longer benefited from positive self-beliefs that mitigate anxiety (Jain & Dowson, 2009), or may have relied on different time-consuming strategies to solve problems (Walczyk et al., 2007).

These results also yielded new information concerning the role of mathematics anxiety and self-efficacy in relation to problem-solving time. Individuals solved the easier 2-digit × 1-digit problems more accurately *and* expediently, as response time were related to self-efficacy. Students with greater degrees of confidence in task success are presumed more accurate in part because they do not divert time-consuming attentional resources to manage stress and anxiety, and are able to effectively calibrate effort (Chen, 2002; Vancouver & Kendall, 2006). This finding is consistent with Eysenck and Calvo's (1992) processing efficiency theory, which indicated that anxiety should not impair on-task performance, or presumably on-task effort, when estimations of confidence are accurate. Consistent with prior research, WMC influenced problem-solving accuracy and efficiency (Ashcraft, 2002; Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Miller & Bichsel, 2004), but only for the more complex problems. The lack of an affect of WMC on less complex problems and the absence of interactive affects may be a result of differential strategy use involved in the solving of mental arithmetic (Hoffman & Schraw, 2009; Campbell & Xue, 2001; DeStefano & LeFevre, 2004) or the substantial influence of positive self- beliefs that boost problem-solving performance (Jain & Dowson, 2009).

In the present study, when more complex problems were encountered, individuals likely perceived an accurate solution less probable, with the criterial task triggering worry or threat. Anxiety invoking circumstances such as these possibly usurped precious working memory resources, normally dedicated towards problem solving. The significant findings for self-efficacy for easier problems and the consistent findings for working memory, in the absence of affects for self-efficacy at higher levels, supports this contention.

Gender and mathematical performance were negatively related confirming previous research (Baloglu & Koçak, 2006; Bandalos et al., 1995; Betz, 1978; Ma & Xu, 2004; Miller & Bichsel, 2004). Although performance differences may be due to ability, in light of the significant gender/self-efficacy correlation, perhaps the pessimistic belief in a successful outcome implies females did not *try* as hard, or put forth the same effort, when assessing the present problems. Previous researchers have found gender differences in mathematics performance were minimized when controlling for the impact of self-efficacy (Hackett & Betz, 1989; Pajares & Miller, 1994). Therefore, gender differences in mathematics efficiency could be explained by the reported difference in self-efficacy, rather than by gender alone.

## 10. Implications

Higher levels of self-efficacy were related to enhanced problem-solving efficiency, without increasing problem-solving time. Expeditious accuracy should be cultivated to prepare students for performance under the perception of stress, such as encountered during standardized testing. Teachers faced with constraints on the problem-solving process should take into account both the beneficial effects of instilling confidence in their students and the potentially adverse effects of anxiety in the face of difficulty.

These results emphasize the need for intervention to limit the consequences of mathematics anxiety. Pre-service teachers are more susceptible to the debilitating effects of mathematics anxiety than most other groups of students (Hembree, 1990). The results implied high self-efficacy and working memory ability are necessary, but not sufficient traits to overcome the detrimental effects of mathematics anxiety. Teachers advocating the utility of mathematics (Brady & Bowd, 2005) and demonstrating an ability to cultivate a sense of domain identification with mathematics may assist in circumventing the onset of mathematics anxiety. Steele (1997) argued cognitive and behavioral strategies such as the "wise schooling approach" which incorporates optimistic teacher expectations, task challenge commensurate with ability, and behaviors which demonstrate an incremental view of intelligence are instrumental in domain identification. Interception of anxiety before it is cultivated may avoid negative self-evaluation to overcome task avoidance and preempt the "I think I can, but I'm afraid to try" approach of many mathematics anxious individuals.

Last, a plausible interpretation of these results may be that problem-solving success is contingent upon the interactive effects between self-beliefs and optimal strategy use as a means to avoid anxiety. Indeed, previous research has indicated individual perceptions and the use of self-regulation strategies such as rehearsal and elaboration (Jain & Dowson, 2009) work together towards reducing anxiety. Walczyk and colleagues (Walczyk et al., 2007; Walczyk & Griffith-Ross, 2006) have repeatedly demonstrated that students use a variety of compensatory strategies to maintain accuracy. These results suggest teachers should consider explicit strategy training in conjunction with an emphasis on promoting positive self-beliefs, which may yield superior problem-solving outcomes without increasing processing time, unlike the outcomes observed in the Walczyk studies. Concurrently, researchers should consider qualitative methods to determine what strategies students employ and how these strategies influence problem-solving efficiency.

## 11. Limitations

Several limitations warrant cautious consideration of these results; restricted sample size, the domain-specificity of results, and the questionable motivation of students during simulated research. The sample size may have lacked power to fully detect the affects of mathematics anxiety; however, the results do lend support to the contention that individual differences variables, such as self-efficacy, may mediate the affects of mathematics anxiety (Jain & Dowson, 2009) and restricted WMC (Hoffman & Schraw, 2009;). Considering the dependency of working memory resources for successful mathematics performance (Ashcraft & Krause, 2007), it is essential that effort be devoted towards identifying any interceding variables which might overcome processing limitations when investigating efficiency outcomes.

These results may not generalize to other types of complex problem solving. Mental arithmetic is a familiar task incorporating defined heuristics in the problem-solving process (LeFevre et al., 1996; Mabbott & Bisanz, 2003; Siegler, 1988). When students are exposed to novel problem-solving situations which demand creativity and resourcefulness, motivational mediators may change. Research is needed to determine the interactive effects of self-efficacy, WMC, and anxiety in other domains perceived less familiar, or more cognitively demanding.

It is unknown in the present study what criteria were instrumental in evoking mathematics anxiety. Anxiety was simulated and not manipulated; thus, observed differences in anxiety may be construed as differences in mathematics knowledge, the availability of cognitive resources, or the motivation of participants. Anxiety was measured at the domain level, but not measured precisely for the particular types of problems in the criterial task. A more task specific measure of anxiety for mental arithmetic may have yielded more precise results. Qualitative research which explores the etiology of mathematics anxiety, and experimental research which controls for social desirability of responses is necessary to accurately measure if anxiety is a consequence of the domain, or dormant based upon the circumstances of measurement.

Last, the results indicated efficiency outcomes are related to motivational factors; however, a conundrum exists concerning the precise components of efficiency. Are more efficient problem solvers able to hold effort in reserve and accomplish superior results through strategy modification, or is efficiency predicated upon accurate calibration of task demands? As Vancouver and Kendall (2006) suggested inaccurate calibration may undermine effort. Future research should focus on the measurement, context, and evaluation of efficiency and determine what variables may accelerate cognitive efficiency.

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