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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

Bobby Hoffman *

University of Central Florida, United States

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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

* Department of Educational Studies, College of Education, P.O. Box 161250, Orlando, FL 32816-1250.
E-mail address: bhoffman@mail.ucf.edu.

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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