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ORIGINAL ARTICLE

From Janet T. Spence's Manifest Anxiety Scale to the Present Day: Exploring Math Anxiety and its Relation to Math Achievement

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Abstract Janet Taylor Spence conducted a great deal of foundational work establishing the negative relation between anxiety and performance. Spence operationalized trait anxiety by creating the Manifest Anxiety Scale, and she conducted numerous studies linking scores on this scale to performance across a variety of cognitive tasks. The field of math anxiety research has built from her work to examine the ways in which negative emotions regarding math can hinder math performance. We discuss the antecedents and development of math anxiety, as well as the ways in which other individual differences, such as working memory, affect the relation between anxiety and performance. Although a rich literature has sprung from Spence's early work, there is much left to do in terms of fully understanding how specific types of anxiety interact with each other, as well as with other individual differences, to determine performance outcomes.

Keywords Anxiety · Performance · Cognition · Math anxiety · Emotion · Memory · Biography

In the 1950s and 60s, Janet Taylor Spence conducted pioneering work on the relation between anxiety and performance. Spence linked individual differences in anxiety levels to performance on cognitive tasks, indicating the importance of addressing the affective, as well as cognitive, factors that influence achievement in order to maximize success. Today, research is building from Spence's work in order to further examine how anxiety develops, varies in the population, and influences daily life.

Spence focused much of her research on manifest anxiety as measured by a scale that she created with the aid of several clinicians (Taylor 1953). *Manifest anxiety* can be conceptualized as a type of trait anxiety, a relatively stable aspect of one's disposition. Several of Spence's studies also explored *state anxiety*, which is momentary anxiety in response to stressful situations (Goetz et al. 2013).

Spence's work on manifest anxiety provided important insight into the nature and effects of trait anxiety. Modern researchers are continuing her work and expanding on her investigations into trait anxiety in a number of ways. For example, today, many different types of trait anxiety are being examined, including test anxiety, literacy anxiety, and math anxiety (Dowker et al. 2016). These types of anxiety may influence each domain of performance differently, and any given person might be subject to some or all of them.

State anxiety has also been subject to further investigation. State anxiety has been found to be prevalent in many different domains because it can be induced by any number of nerve-wracking experiences one might encounter in the world. For example, stereotype threat can be thought of as a form of state anxiety. Stereotype threat occurs when a member of a stereotyped group is made aware of the low expectations that society has for their group, and the resultant worry leads to decreased performance (Walton and Spencer 2009). For instance, stereotype threat may lead women to perform poorly on math or computer science tests because they are preoccupied by anxiety at the thought of preforming poorly, thus confirming negative stereotypes about their gender. State anxiety may also result from other high pressure situations, such as in the classroom, where students face important tests; in the workplace, where an employee 's work is being evaluated by a superior; or in a sports arena, where an entire team or nation may be

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heavily invested in an athlete's performance (Beilock and Carr 2001; Beilock and Carr 2005). Spence began the work of investigating the effects of state anxiety on performance by putting participants in high-pressure situations in the lab and then measuring subsequent task performance, a technique that is still used today (e.g., Beilock and Carr 2005; Walker and Spence 1964).

Other individual differences that can influence the nature of the relation between anxiety and performance are also being investigated. For example, working memory, the system that organizes and stores information for short periods of time (Miyake and Shah 1999), has been found to moderate the relation between anxiety and performance, hinting at one mechanism by which anxiety relates to performance (Beilock and Carr 2005). Spence's early work provided the foundation for these more nuanced investigations.

Relation between Anxiety and Performance

To quantify anxiety for use in cognitive psychology studies, Spence developed the Manifest Anxiety Scale (MAS; Taylor 1953). The scale was based on a standardized personality test called the Minnesota Multiphasic Personality Inventory (MMPI; Hathaway and McKinley 1940). Spence selected items from the MMPI to submit to five clinicians, who identified the items most likely to be associated with anxiety. Spence used these items to develop the Manifest Anxiety Scale. The scale has been refined over the years, and it currently consists of 50 statements about anxiety, such as "I sometimes feel that I am going to pieces," which participants are asked to rate as true or false.

After the scale was created, a series of studies was able to establish and describe the relation between manifest anxiety, operationalized as a score on the MAS, and performance on a variety of cognitive tasks. In 1952, Taylor & Spence found that those with low scores on the MAS performed significantly better than those with high scores on a serial learning task. The task involved learning the order in which a series of directional lefts and rights were presented on a memory drum. It was the most cognitively demanding parts of the task that showed the greatest performance difference between the high and low anxious groups. Highly anxious participants made more errors on the task, especially at the difficult decision points, and took longer to reach learning criterion.

This finding would parallel later work suggesting that tasks that require a great deal of working memory resources are the ones most negatively affected by the presence of anxiety (e.g. Ashcraft and Kirk 2001). This was a clear example of how trait anxiety, as measured by one particular scale, could account for individual differences in performance on a cognitive task.

Additionally, in 1959, Taylor and Rechtschaffen found that scores on the MAS were negatively correlated with performance on the cognitively demanding task of printing the alphabet backwards and upside down, thus providing further evidence for a link between anxiety and performance. They also looked at the correlation of performance with five different subscales of the MAS (chronic anxiety, motor tension, physiological reaction to emotional stimuli, inner strain associated with sleep difficulty, and a sense of personal inadequacy), as well as a sixth subscale composed of those items that did not make it onto any of the other subscales. Three of the subscales were significantly negatively correlated with task performance, whereas two others showed a negative, but nonsignificant relation, indicating that there are several different subcomponents of anxiety, and many of them may be important factors in determining performance on cognitive tasks. The only subscale that was not negatively related to performance involved physiological reactions, including blushing and sweating from embarrassment. Given that this task took place in a laboratory setting with confidential results, it may be that this task was not well suited to capture that subscale.

To investigate a possible mechanism by which anxiety harms performance, Spence looked at whether highly trait anxious people were more susceptible to being distracted by state anxiety (Taylor 1958). This study involved inducing anxiety to examine the link between state anxiety and performance and to examine how the relation between state anxiety and performance might differ as a function of trait anxiety. Participants were selected based on their performance on the MAS and divided into two extreme groups: those scoring 23 or above (high anxious) and those scoring 9 or below (low anxious). Participants were then asked to memorize lists of nonsense syllables. After they had completed a practice list and a first experimental list of syllables, pressure was induced into some participants by telling them that they had performed more poorly than most others and by asking them to improve their performance on the final list. Participants in a control condition were simply told that they were about to learn a new list of syllables.

Spence found a main effect of anxiety, with high anxious participants outperforming low anxious participants on the first experimental list before any anxiety induction had been performed (Taylor 1958). Spence speculates that under these neutral conditions, high anxious participants performing this simple task may have actually been more driven, and thus more successful, than low anxious participants. This contrasts with her other findings (Taylor and Rechtschaffen 1959; Taylor and Spence 1952), when participants were engaged in more complex tasks.

Spence also found a main effect of state anxiety, such that participants who did not undergo a pressure induction outperformed those who did on the final list (Taylor 1958). However, Spence found no significant interaction between the effect of trait anxiety and the effect of the pressure induction, perhaps providing evidence that those who are high trait anxious are not more susceptible to state anxiety, but rather that state and trait anxiety contribute independently to performance. This study laid the foundation for future examinations of the relation between state and trait anxiety.

In 1964, Walker and Spence again examined the effects of state anxiety. They tested participants' digit span, or the number of digits in a row that participants were able to remember, under neutral and high-pressure conditions. The high-pressure condition involved informing participants, who were college undergraduates, that a faculty advisor had seen their scores on the MAS and on Sarason and Mandler's (1952) Test Anxiety Questionnaire (TAQ) and suggested that they needed to be subjected to an IQ test. Participants in the control condition were told that they would be taking an intelligence test, but their performance would be anonymous.

Although they found no significant difference between the high pressure and control groups, Walker and Spence (1964) did find that those in the experimental group who reported being bothered or upset by the pressure induction performed significantly worse than control participants did. These findings indicated that pressure can affect individuals differentially depending on how they subjectively interpret the emotions elicited by the manipulation. Different individuals may differentially experience performance pressure in the same situation, depending on their disposition, beliefs, and values. In Walker and Spence's study, for example, some participants may have been very upset that a faculty advisor felt that they needed an IQ test, whereas others may not have minded (or may not have believed the experimenter).

This early work had many implications for the effects of anxiety on performance. For example, these studies indicate that several different facets of anxiety can contribute independently to performance (e.g. manifest anxiety, state anxiety, test anxiety,).

The Effect of Math Anxiety on Math Performance

Today, we are expanding on Spence's work to learn more about the relation between anxiety and performance. To examine this relation in more depth, we often focus on specific types of trait anxiety. For example, math anxiety (apprehension or fear related to math) has been examined in great detail (Ashcraft 2002). Anxiety about mathematics is prevalent in the United States and across the world. In fact, at the country level, greater math anxiety is correlated with lower performance on the Programme for International Student Assessment (PISA), an international test given to 15-year-olds across the world. Additionally, within each country, greater math anxiety is associated with lower math performance (Foley et al. 2017).

In the United States, math-anxious students take fewer elective math courses, both in high school and in college, than do people with low math anxiety (Hembree 1990). Yet even when they avoid math class, math-anxious individuals still find math stressful in many other contexts, from reading a receipt to doing simple subtraction (Alexander and Martray 1989). Additionally, math anxiety is more predictive of math performance than of IQ-test performance or verbal aptitude, indicating that math anxiety is not simply a proxy for more general performance deficits (Ashcraft 2002). Thus math anxiety is a prevalent, distinct, and important type of trait anxiety. Fortunately, Spence laid the foundation for us to investigate math anxiety and its impact on math performance in both the lab and the classroom.

Like Spence's Scale of Manifest Anxiety, simple surveys are often used to operationalize math anxiety in both adults and children. One such scale through which math anxiety can be measured is the Short Math Anxiety Rating Scale, or sMARS (Alexander and Martray 1989). The scale involves asking participants to rate how anxious they would feel in a variety of everyday situations involving math. For example, they rate how they would feel "studying for a math test" or "walking to math class." A higher rating on the scale corresponds to more math anxiety in daily life.

There is a great deal of evidence that students who report being anxious about math on scales like the sMARS score lower in tests of math achievement (Ashcraft and Krause 2007; Dowker et al. 2016; Ramirez et al. 2016). Although the direction of this relation is not entirely clear (poor math performance may cause anxiety, just as anxiety may cause poor math performance), a number of studies have been conducted to try to tease apart the various influences of ability and emotion on performance.

Math-anxious individuals may show deficits in mathematical processing that lead them to have poor math performance, which in turn engenders mathematics anxiety. For example, individuals who report high levels of math anxiety show increasing deficits in quickly identifying the exact number of squares displayed on a screen as the numbers grow from 1 to 9 (Maloney et al. 2010), and they are slower than low anxious individuals are at identifying the larger of two numbers (Maloney et al. 2011). These basic deficits may lead to the development of math anxiety or may interact cyclically with math anxiety.

Math anxiety may also be transmitted via social interactions, especially early in development. For example, Beilock et al. (2010) found that elementary school girls with high math-anxious teachers exhibited lower math performance at the end of the school year than did girls with low math-anxious teachers. This effect was mediated by the girls' endorsement of the gender stereotype that girls are not good at math. The same degree of impact was not seen in boys. Girls may have picked up on this message in the classroom from their high math-anxious female teachers, who may differ from low anxious female teachers in many respects. These teachers may, for example, deliver lessons differently, talk about their attitudes toward math differently, respond differently to students' questions or errors, or even explicitly endorse gender stereotypes about mathematics.

The interactions that parents have with children could also be a mode for transmission of math anxiety. Maloney et al. (2015) found that the children of high math-anxious parents make smaller gains in math throughout the course of the school year than did the children of low math-anxious parents, although this effect only held if the high math-anxious parents frequently provided homework help. It could be that, much like teachers in the classroom, high math-anxious parents respond differently to their children during homework help than low math-anxious parents do, thus harming their children's math learning.

Structuring parents' and children's interactions around math may provide math-anxious parents with the scaffolding that they need to have a productive math interaction with their child. For example, a version of an iPad application called "Bedtime Math" (2017) has been found to diminish the gap in achievement between the children of high and low math-anxious parents (Berkowitz et al. 2015). Thus high math-anxious parents and teachers may simply lack the tools to interact positively with children around math. When these adults are provided with the proper resources, they may be able to shrink the anxiety/performance achievement gap.

Working Memory: Anxiety Disrupts Performance

Examining trait math anxiety also allows us to delve deeper into the anxiety/performance link established by Spence and build from many important aspects of her findings. For example, in Taylor and Spence's (1952) study of anxiety's impact on serial learning, anxiety had the largest effect on the most challenging portion of the task. We could conceive of this portion of the task to be the part that required the most working memory.

This finding parallels current work suggesting that high working memory tasks are the ones most negatively affected by dispositional trait anxiety or induced state anxiety (Beilock and Carr 2005; Ramirez et al. 2016; Ashcraft and Kirk 2001; Ashcraft and Krause 2007). Working memory is a limited capacity system that can be compromised by anxiety-induced thoughts and ruminations (Miyake and Shah 1999; Beilock and Carr 2005). Math anxiety, test anxiety, and stereotype threat have all been shown to tax the working memory system, leading to decreased performance on tasks that demand heavily on it. Although anxiety can come from several sources, working memory is thought to be a shared mechanism by which anxiety disrupts performance (Beilock and Carr 2005; Schmader and Johns 2003).

For example, Ashcraft and Kirk (2001) reported that math anxiety is more strongly linked to performance for the working-memory intensive task of addition involving a carry operation than for simpler arithmetic. Additionally, Ashcraft and Kirk found that math-anxious individuals suffer performance deficits when they are asked to complete a secondary working-memory intensive task, like holding letters in mind, while performing simple math problems.

The relation among working memory, anxiety, and performance is revealed via task differences not only in working memory requirements, as Taylor and Spence discovered in 1952, but also in individual differences in working memory capacity. For example, in one study of math anxiety, first and second graders who demonstrated high working memory capacity on a forward and backward digit span task showed a negative relation between math anxiety and performance whereas their low working memory peers did not (Ramirez et al. 2016). This effect was mediated by high working memory children's switch from more efficient math strategies, (such as decomposition to solve a subtraction problem) to less efficient strategies (such as counting or relying on retrieval from memory). Children with lower working memory capacity did not show as strong a relation between working memory and performance, perhaps because they had been using less working-memory intensive strategies all along. Thus anxiety can lead to the use of inefficient problem-solving strategies, particularly among those with high working memory who are most likely to use these strategies.

This gap persists throughout development, with high school and college students with high working memory consistently showing a stronger relation between anxiety and performance than low working memory students (Beilock and Carr 2005). Even on international tests, such as the PISA, students performing in the 90th percentile at math show a stronger negative relation between math anxiety and performance than those at the 10th percentile, indicating that it is the students with the greatest cognitive capacity who are most negatively impacted by this relation (Foley et al. 2017). Thus anxiety may well tie up working memory, such that tasks that require working memory are performed poorly, and individuals who tend to rely heavily on working-memory intensive strategies are the most disadvantaged.

There is also converging fMRI evidence (Young et al. 2012; Lyons and Beilock 2011) implicating working memory as a mechanism by which anxiety hinders performance. Young et al. (2012) found that high math-anxious 7- to 9-year-old children, when performing basic math problems, showed increased activation in the right amygdala, a region associated with processing negative emotions, as compared to low math-anxious children. Importantly, the children also showed decreased activation in the dorsolateral prefrontal cortex and posterior parietal lobe, areas implicated in working memory and numerical reasoning (see Lyons and Beilock 2011 for converging evidence in adults).

In light of the toll that anxiety appears to take on performance, especially for those with the most working memory capacity available to them, interventions have been developed to mitigate anxiety's detrimental effect on performance. For example, Jamieson et al. (2010) found that telling students that feeling nervous, and thus physiologically aroused, before a test improves test performance lead to higher GRE scores, both in the lab and on test day, than controls who had no such interventions. This work harkens back to Walker and Spence's (1964) finding that students who report feeling upset by pressure demonstrated worse performance. Again, it was the students' interpretation of their emotions related to the stressful situation, rather than any objective event, that lead to decreased performance.

Additionally, Ramirez and Beilock (2011) found that asking students to spend 5 minutes writing about their feelings before a high stakes math test lead to improved performance. Writing about worries was also found to reduce the math achievement gap between high and low math-anxious individuals (Park et al. 2014). In these examples, helping student to re-interpret or re-frame their emotions may have allowed for working memory resources to be freed up and performance to be enhanced.

Stereotype threat can also be targeted more specifically. For example, increasing African American students' sense of belonging at college (Walton and Cohen 2011) or women's sense of belonging in engineering programs (Walton et al. 2015) can improve the college grade point average of these groups. Perhaps mitigating fears about being unwelcome or negatively stereotyped reduces cognitive load, freeing up working memory capacity for academic pursuits.

The fact that brief interventions can significantly improve performance indicates that anxiety does indeed play a role in keeping students from maximizing their potential. Thus it is unlikely that anxious people are just less capable than others, but rather it is likely that their anxiety prevents them from achieving all that they otherwise could.

Future Directions

Although much has been accomplished in the past 60 years, there is still a great deal to be learned about the relation of anxiety to performance. Spence greatly contributed to anxiety research by operationalizing manifest anxiety through the creation of her scale. Yet it remains unclear exactly how anxiety develops and changes throughout the lifespan. Evidence from the literature on math anxiety indicates that there may be a cyclical relation between anxiety and performance: Anxiety causes poor performance, which in turn engenders greater anxiety and a lack of confidence in one's abilities, and the relation likely goes the other way too, with poor performance causing anxiety, and so on (Carey et al. 2016). However, the exact nature of this relation needs to be examined in more detail, especially from a developmental standpoint.

There is also a great deal still to be learned about how performance is impacted by the relations among working memory, state anxiety, and trait anxiety. Spence's early investigations into these interactions involved examining how high- and low-anxious individuals operate in high- and low-pressure situations (Taylor 1958; Walker and Spence 1964). Although more recent research has provided evidence that individuals with high working memory show the greatest negative relation between state anxiety and performance (Beilock and Carr 2005), it remains unclear how trait anxiety interacts with this phenomenon. Incorporating individual differences in working memory into our understanding of anxiety will allow us to form a more complete picture of how various types of anxiety interact and develop.

Furthermore, although we have learned that adults can transmit anxiety to children (Beilock et al. 2010; Maloney et al. 2015), the exact nature of this transmission remains unclear. For example, the mechanism by which math-anxious teachers harm their students' (and especially girls') learning has yet to be uncovered. Further study needs to be done in order to discover what is going on in the classrooms of high and low math-anxious teachers that leads to different learning outcomes. Ideally, teacher-training programs could then implement interventions to alleviate math anxiety or prevent teachers from revealing their anxiety to students.

The same could be done for high math-anxious parents, whose unstructured interactions with their children can be detrimental to their children's math learning (Maloney et al. 2015). It would be beneficial to gain more insight into how high and low math-anxious parents interact differently with their children when giving homework help or in daily life generally. It may be that low math-anxious parents have higher expectations of their children when it comes to math, or that they are better at explaining math concepts to the children, or that they are less likely to say negative things about math in front of their children. All of these possibilities should be investigated in future work.

Additionally, although successful interventions have been found to mitigate the negative relation between performance and anxiety (Jamieson et al. 2010; Park et al. 2014; Ramirez and Beilock 2011), the exact mechanism of this mitigation is not currently known. For example, writing interventions may be beneficial because they encourage students to reappraise their arousal or because they provide an emotional outlet during a time of stress. It is also unclear how different interventions may interact together. For example, would writing about one's feelings and undergoing an arousal-reappraisal manipulation lead to even greater benefit than either one alone?

Finally, a considerable amount is known about how anxiety influences students' performance on tests, but far less is known about how anxiety may influence learning in the first place. It could be that highly anxious students learn less material than less anxious students and that this deficit negatively impacts their performance in addition to whatever is lost through anxiety at the time of the test. Spence's work hinted at this possibility because it took her anxious participants longer to reach learning criteria in a spatial learning task (Taylor and Spence 1952). This connection could have important implications in the classroom, and interventions may be needed to prepare teachers to reduce students' anxiety before or during lessons. Future work could expand on Spence's early findings to bear this out.

Conclusion

Since the 1950s, much progress has been made in understanding the relation of anxiety to performance. Starting from the basic premise that emotions can impact cognitive tasks, scales were developed to assess negative emotional states such as anxiety, and experiments were undertaken to examine the effect of anxiety on performance across different tasks in different domains.

Many studies over the course of decades provide strong evidence that anxiety is negatively related to performance across a variety of cognitive tasks (e.g. Ashcraft and Krause 2007; Foley et al. 2017; Walker and Spence 1964). This association is especially true for individuals high in working memory (Beilock and Carr 2005) and for tasks that require a great deal of working-memory resources (Ashcraft and Kirk 2001). We see this in lab studies where participants who are higher in trait anxiety perform worse than those who are lower in trait anxiety (Taylor and Rechtschaffen 1959) and where participants who are upset by pressure-induced state anxiety perform worse than those in neutral or relaxed conditions (Walker and Spence 1964). We also observe this pattern in real-world environments where anxiety about a test, such as a final exam or the GREs, may harm performance unless a manipulation to alleviate anxiety is used (Jamieson et al. 2010).

More nuanced definitions of anxiety have been formed, distinguishing state and trait anxiety as well as various types of trait anxiety, such as test and math anxiety (Dowker et al. 2016). Spence started to look at how these various types of anxiety may interact with one another (Taylor 1958), but there is still work to be done in determining how these various anxieties hang together and combine to influence performance outcomes. Although we have come a long way, we still have much work left to do in order to truly understand the relations among cognitive factors, affective factors, and performance outcomes.

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