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Endogenous and exogenous time pressure: Interactions with mathematics anxiety in explaining arithmetic performance

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ABSTRACT

Eighty adults performed mental arithmetic under endogenous (time limit) or exogenous (presence of a clock) time pressure. Results demonstrated a significant interaction between math anxiety and endogenous pressure: error rates were significantly greater among high math anxious individuals when given a time limit. A significant interaction was observed between exogenous time pressure and math anxiety: performance of low math anxious individuals was reduced when a clock was present. Effects were only present in response to problems involving a carry operation, supporting previous findings that math anxiety may be particularly detrimental on math problems that rely more on working memory resources. The findings suggest that the type of time pressure may need to be taken into account when designing assessments.

1. Introduction

Research has demonstrated a consistent relationship between math anxiety and arithmetic performance (Hembree, 1990; Ma, 1999). However, the relationship is more complex than it appears. For example, studies have shown that math anxiety effects are greater in response to math problems that place higher demands on working memory, particularly those problems involving a carry operation (Ashcraft & Faust, 1994; Faust, Ashcraft, & Fleck, 1996), suggesting that math anxiety consumes valuable working memory resources. This was explored further by Ashcraft and Kirk (2001) who gave low and high math anxious participants a math task involving carry and no-carry problems. They were also given either a two-letter (low working memory load) or six-letter (high working memory load) concurrent task. Performance in the low load condition did not differ as a function of math anxiety, but in the high load condition high math anxious individuals performed significantly worse on problems that required a carry operation. The results suggest that math anxiety may be particularly detrimental on math problems that rely more on working memory resources.

However, there have been alternative suggestions concerning the mechanisms that underpin the relationship between math anxiety and performance, including the suggestion that math anxiety may be related to a deficient inhibition mechanism. That is, an inability to inhibit task-irrelevant distractors. Indeed, Hopko, Ashcraft, Gute, Ruggiero, and Lewis (1998) provided evidence of a weakened disinhibition mechanism among highly math anxious individuals, albeit not specific to math stimuli. However, in a later study using a card version of the numeric Stroop task, Hopko, McNeil, Gleason, and Rabalais (2002) found evidence that high math anxious individuals have an inability to inhibit attention towards

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irrelevant information. They observed that the high math anxious group took significantly longer to respond in the numeric task compared to the control (letter) task, whereas no significant difference was observed in the low math anxious group.

In addition to the observed effects on math performance, math anxiety has been shown to be related to the general avoidance of math, as reported in Hembree's 1990 meta-analysis. It has also been discussed in terms of local-avoidance, with very highly math anxious individuals responding quickly to more difficult math problems, possibly as a speed-accuracy trade-off (Ashcraft & Faust, 1994). Interestingly, Roskes, Elliot, Nijstaf, and De Dreu (2013) studied the effect of time pressure as a function of avoidance motivation versus approach motivation. The former represents striving to avoid failure and was measured by scale items such as "when it looks like something bad could happen, I have a strong urge to escape". The researchers observed that performance was particularly negatively affected under time pressure among those who are avoidance motivated. In this instance time pressure was induced by setting a time limit for each math problem. Roskes et al. discuss the findings partly in relation to avoidance motivation evoking a processing style that is resource demanding, with factors such as time pressure adding to the already limited cognitive resources available for task engagement. This proposition has parallels with an attentional control account of anxiety effects on cognitive performance (Eysenck, Santos, Derakshan, & Calvo, 2007). According to attentional control theory, anxiety causes an imbalance between the stimulus-driven attentional system and the goal-directed attentional system. Math anxiety as an inhibition/attentional control deficit can be conceptualised in terms of how math anxious individuals may attend to information that is not part of the goal-directed attentional system. This may be in the form of exogenous task-irrelevant distractors, or in the form of intrusive or worrisome thoughts that impede or consume working memory resources (Hopko et al., 1998).

There is some evidence to suggest that worrisome thoughts are indeed associated with math anxiety. For example, Hunsley (1987) found that self-reported math anxiety accounted for a significant proportion of variance in negative internal dialogue experienced during a math exam. Also, DeCaro, Rotar, Kendra, and Beilock (2010) observed a significant negative correlation between the number of self-reported task-related thoughts and problem solving accuracy. However, the nature of worrisome thoughts proposed to be experienced as a result of math anxiety has been somewhat speculative, although there are some empirical findings that indicate what such thoughts may consist of. For example, Beilock, Kulp, Holt, and Carr (2004) asked participants to perform arithmetic in a high pressure condition and noted that they had significantly higher perceptions of performance pressure than those in the low pressure condition. In the high pressure condition participants were also more likely to report thoughts and worries about the situation and its consequences.

Faust et al. (1996) provided some evidence to suggest that time pressure creates an increased cognitive load, which particularly impacts individuals high in math anxiety. They observed that the negative consequences of math anxiety disappeared when participants were tested in an untimed paper-and-pencil condition, in which cognitive load was reduced. To directly assess the relevance of time pressure on the relationship between math anxiety and performance, Kellogg, Hopko, and Ashcraft (1999) gave low and high math anxious individuals a series of math problems under timed and untimed conditions. They observed an overall positive relationship between math anxiety and number of errors made, but this did not vary according to timed or untimed conditions, suggesting that time pressure may not be as important as first predicted in explaining the effect of math anxiety on performance. Kellogg et al. (1999) suggested that task-related cognitions may be more directly related to factors other than time pressure, such as the presentation of math stimuli or physiological arousal. However, recent work has demonstrated that, even under non-timed conditions, 49.2% of participants self-reported having thought about time pressure during an arithmetic test situation. Moreover, self-reported math anxiety was significantly higher among those who had experienced thoughts about time pressure (Hunt, Clark-Carter, & Sheffield, 2014). Furthermore, in their study, Kellogg et al. allowed participants to utilise the blank space on the paper provided to write down their workings out. It is possible that this approach might actually benefit high math anxious individuals, such that fewer working memory resources are required compared to maintaining calculation steps in working memory (c.f. Faust et al., 1996). As such, the findings of Kellogg et al. cannot be generalised to all test situations.

It is feasible that the precise way in which time pressure is implemented is important in studying the effects of math anxiety. For example, time pressure could include: an overall predetermined timeframe that participants have to complete a task, smaller timeframes in which to complete sub-tasks or individual items, a modified timeframe based on an individual's concurrent performance, notification of the start and end of a task, regular verbal and visual reminders of time remaining, and constant verbalisation or visualisation of time remaining. Bosmans and De Smedt (2015) tested math performance of children under timed and untimed conditions and observed a significant negative direct relationship between math anxiety and performance in both conditions. In their study, the timed condition required participants to respond to columns of math problems, solving as many as possible within one minute, demonstrating one particular way of creating a timed condition. Also, Bosmans and De Smedt did not test the effect of time pressure on performance as a function of problem type, which, as discussed previously, is an important factor to consider when testing math anxiety effects on arithmetic performance.

Surprisingly little research has been conducted into the precise nature of time pressure and how this may relate to math anxiety and arithmetic performance. Moreover, consistent findings concerning the relationship between math anxiety and intrusive thoughts about pressure, and even time pressure specifically, warrant further investigation. In the context of math anxiety, the extent to which time pressure acts as an endogenous distractor and gives rise to intrusive thoughts has not been considered in relation to exogenous distractors that act as a constant reminder of the time. Given that real-world test scenarios, such as exam halls, often involve a constant visual reminder of the time in the form of a clock, the current study manipulated time pressure by asking participants to perform mental arithmetic problems under time pressure or no time pressure, with or without the presence of a clock. It was hypothesised that self-reported math anxiety would have a negative