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Short Report

Effects of Pressure-induced Worry and Negative Thoughts on Verbal and Visuospatial Working Memory Capacity

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Abstract

The purpose of this study was to examine the effects of pressure-induced worry/negative thoughts on verbal and visuospatial working memory (WM) capacity. Twenty-six participants performed two WM tasks (verbal: reading span; visuospatial: spatial span) under baseline and pressured conditions. The results indicated that spatial span declined when participants were under pressure, but reading span performance did not. These results suggest that pressure-induced worry and negative thoughts decrease visuospatial WM capacity. The rationale for pressure-induced worry and negative thoughts not affecting verbal WM is that the practice effect of reading span was not controlled in this study.

1. Introduction

Individuals want to perform at their best in important test situations. However, such conditions often make them perform worse than usual. Pressure is a factor that increases with the importance of a task[1]. It is the motivation from inside or the expectation from outside for high performance. The phenomenon whereby individuals perform worse than expected, given their skill level, because there are large incentives for their best performance, and the phenomenon of worrying about the consequences of poor performance is called "choking under pressure". Distraction theory explains the mechanism of choking under pressure. This theory proposes that pressure is a distraction, thereby drawing a performer's attention away from skill execution[2,3].

Beilock et al.[4] support the distraction theory of choking under pressure. Their assumption is that pressured individuals fail because pressure reduces working memory (WM) capacity as an attentional resource, which is the key to success. WM is a short-term memory system, which, in an active state, maintains a limited amount of information relevant to the task at hand[5]. Beilock et al.[4] investigated the effects of pressure on performance with respect to mathematical problems. Participants under high- and low-pressured conditions were required to perform high- and low-demand mathematical problems. They manipulated WM demands by manipulating task difficulty as high-demand mathematical problems rely

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more heavily on WM than do low-demand mathematical problems. Before performing the tasks, the participants under high-pressured conditions were informed of three high-pressure scenarios: monetary incentives, peer pressure, and social evaluation. The results showed that under these high-pressured conditions, the performance in high-demand mathematical problems declined but did not in low-demand mathematical problems. This suggests that high-demand mathematical task performance declined because pressure-induced thoughts reduced WM capacity to succeed in the high-demand mathematical task. Beilock et al.[4] required participants to answer a verbal thought report to explore their thoughts and feelings while they performed. Participants under high-pressured conditions reported worries about the situation and its consequences. These results suggested that mathematical performances under pressured conditions declined because the worries induced by pressure reduced the WM capacity available for performance.

Baddeley and Hitch[6] proposed a multicomponent model of WM that consists of three functional components. The central executive component is envisioned as a control system of limited attentional capacity that is responsible for the manipulation of information within WM and for controlling two subsidiary storage systems: the phonological loop and the visuospatial sketchpad. The phonological loop is assumed to be responsible for the storage and maintenance of information in phonological form, whereas the visuospatial sketchpad is dedicated to the storage and maintenance of visual and spatial information[7]. In addition, Shah and Miyake[8] proposed that WM capacity is supported by two separate pools of domain-specific resources for verbal and visuospatial information. The combination of the phonological loop and the central executive component is called verbal WM, and the combination of the visuospatial sketchpad and the central executive component is called visuospatial WM.

DeCaro et al.[9] considered that if pressure induces internal verbal expressions of worry and negative thoughts, it is possible for these thoughts to tax the phonological aspect of WM more heavily than they tax the visuospatial aspect. They investigated the effects of pressure on participants under low- and high-pressure conditions who were asked to perform horizontal and vertical mathematical problems. Trbovich and LeFevre[10] demonstrated that mathematical problems presented in a horizontal format depend heavily on verbal resources, whereas those presented in a vertical format depend heavily on visuospatial resources. After completing verbal and visuospatial WM tasks, the participants were required to answer a verbal survey exploring their thoughts and feelings while they performed. The results indicated that participants under high-pressure conditions reported more worry and negative thoughts than did participants under low-pressure conditions. Horizontal mathematical problem performance declined under high-pressure conditions, whereas vertical mathematical problem performance did not. There was a significant correlation between increased worry and negative thoughts and decreased verbal-based horizontal mathematical performance. DeCaro et al.[9] suggested that pressure-induced worry or negative thoughts reduced verbal WM capacity but did not reduce visuospatial WM capacity.

However, in studies on the relationship between anxiety and WM, some findings have differed from those of DeCaro et al.[9] Eysenck and Calvo[11] proposed processing efficiency theory (PET), which assumes that anxiety affects the central executive component more strongly than it affects the phonological loop or the visuospatial sketchpad. In a recent study based on PET theory, Owens et al.[12] explored the relationship among the performance of WM tasks (tasks of the central executive, phonological loop, and visuospatial sketchpad), trait anxiety, and test worry. Their results showed that anxiety interfered most strongly with central executive task performance and that the relationship between anxiety and WM was mediated by test worry. More recent research has indicated that situation-induced anxiety decreased performance on verbal and visuospatial WM tasks. Vytal et al.[13] investigated the effects of the threat of shock on verbal and spatial WM tasks (1-, 2-, and 3-back WM tasks). Their participants performed WM tasks under both threatened and safe conditions. Participants under the threat condition often received threats, such as those of electric shocks, whereas those under the safe condition did not receive such threats. Their results showed that the threat of shock decreased 1- and 2- back verbal and spatial WM task performance. Moran[14] reviewed a great number of studies regarding anxiety and WM and consistently found that anxiety affects the central executive component in WM but found no consistent evidence that anxiety affects verbal (phonological) or visuospatial WM.

Although studies regarding anxiety have argued that anxiety affects the central executive component, DeCaro et al.[9] have indicated that worry and negative thoughts particularly affect verbal WM. It is possible that the differences between the findings of the anxiety studies and those of DeCaro et al.[9] were caused by the differences in task type. A WM task was employed in the studies regarding anxiety. However, a mathematical task was employed by DeCaro et al.[9]. Although a mathematical task depends on WM, it is not a task that is designed to measure WM capacity. Given the previous studies regarding anxiety, we set out to employ WM tasks to investigate the effects of pressure on WM. The purpose of this study is to demonstrate the effects of pressure-induced worry/negative thoughts on verbal and visuospatial WM capacity using WM tasks. We used a reading span task[15,16] as a verbal WM task and a spatial span task[8] as a visuospatial WM task. We required participants to perform verbal and visuospatial WM tasks under both baseline and pressured conditions. Considering the results of previous studies regarding anxiety and WM, it is possible that pressure-induced worry or negative thoughts also affect the central executive component. We predicted that both verbal and visuospatial WM task performance would decline under pressured conditions because the central executive component is a general component of both verbal and visuospatial WM.

2. Methods

2.1 Participants

Twenty-six undergraduate students (male: 4; female: 22) were recruited. The average age of the participants was 22.0 years (SD = 0.5).

2.2 Procedures

All participants performed under the same baseline and pressured conditions. Under the baseline condition, participants performed both verbal and visuospatial WM tasks after two practice trials. Then, they completed two questionnaires.

Following the baseline condition, each participant was informed of three pressure scenarios that were based on previous studies[4,9,17]. First, participants were told that if they could improve their WM task score by 20% relative to the preceding trials, they would receive a reward (some stationery worth 500 yen). In addition, the participants were informed that they had been paired with another participant for a "team effort" and that if both a participant and their imaginary partner improved, each would receive a greater reward (more stationery worth 500 yen for a total reward worth 1000 yen). However, if either the participant or their partner did not improve by 20%, neither would receive the additional reward. Next, the participants were told that the partner had already completed the experiment and had improved by 20%. Therefore, if the participant improved by 20%, both the participant and the partner would receive the reward. However, if the participant did not improve, neither would receive the additional reward. Finally, the participants were told that their performances were recorded so that during the post-test block, the experimenters could examine their performance on the two WM tasks.

After these pressure scenarios were communicated, the participants performed the WM tasks and completed two questionnaires regarding their experiences of pressured conditions. Finally, the participants were debriefed, and they were given the reward (stationery worth 1000 yen). The order of verbal and visuospatial WM tasks was counterbalanced.

2.2.1 WM tasks

We used the Japanese edition of the reading span task[15,16] as a verbal WM task. The participants were asked to read a series of unconnected sentences aloud and memorize the underlined word in each sentence in a series. Then, the participants were asked to recall the memorized underlined words in their original order when a blank screen was presented at the end of each set. After they recalled the words, the participants pressed the enter key to start the next trial. The reading span task involved four spans and included a total of 20 sentences divided into five sets, with the number of sentences in each set ranging from two to five and increasing as the participant progressed. The reading span task was continued until the participant failed to recall two or more underlined words. In this study, the participants performed the reading span task under pressured conditions immediately after performing it under baseline conditions. As we predicted, a practice effect was observed in the pressured condition. We used two patterns of reading span: that of Osaka[16] and another consisting of different sequences of the sentences used by Osaka[16]. The order of the two reading spans was counterbalanced between the baseline and pressured conditions.

We developed a visuospatial WM task based on Shah and Miyake[8] using a spatial span task[8] in which the participants were asked to judge whether the letters (R, L, F, and P) were normal or mirror-images, as well as to memorize the direction in which each letter was rotated in one of the seven possible orientations (45°, 90°, 135°, 180°, 225°, 270°, and 315°). The participants responded aloud as to whether each letter was "normal" or a "mirror-image" and memorized the direction of each letter. They pressed the enter key to make the next letter appear on the screen. After the set of letters was presented, the participants recalled the directions and reported them using a paper with a diamond-shaped grid. They were required to indicate the direction that the top of each letter had been facing in the order of appearance. After they recalled the directions, the participants pressed the enter key to start the next trial. As with the reading span task, the spatial span task included a total of 20 letter sets, with five sets at each level containing anywhere from two to five letters and increasing in length as the participants progressed. The test was continued until the participants failed to recall two or more trials. We prepared two patterns for the spatial span task to alleviate the practice effect under pressured conditions. The order of the two spatial span tasks was counterbalanced between the baseline and pressured conditions.

2.2.2 Measurements

We used a retrospective verbal report[9]. The participants were required to remember their thoughts and feelings during the performance of each WM task and to describe their thoughts and feelings in writing in as much detail as possible. Furthermore, participants rated the degree of subjective pressure in the last condition on a seven-point scale (1 = I did not feel pressure at all to 7 = I felt strong pressure.)[9].

2.3 Ethical considerations

The participants were informed with regard to the purpose and procedure of this study. Before the experiment, the participants were informed that the aim of this study was to examine the relations between emotion and working memory. Although, when debriefed, they were told that the aim of this study was to examine the effect of choking under pressure on working memory. They were also informed that the obtained data would be strictly managed and stored. This study was carried out after receiving the approval of the ethics committee at the Kawasaki University of Medical Welfare (Approval number: 16-077).

3. Results

3.1 Subjective pressure questionnaire

A paired samples t-test was conducted to compare the subjective pressure scores under baseline conditions with those under pressured conditions. There was no significant difference in the pressure scores for the baseline (M = 5.33; SD = 1.40) and the pressure (M = 5.33; SD = 1.52) conditions, t (25) = 0.00, *n.s.* These results show that the participants under pressured conditions did not feel subjective pressure. It also indicates the possibility that pressure manipulation in this study failed.

3.2 Retrospective verbal report

We divided the responses on the retrospective verbal report into five categories based on DeCaro et al.[9]. Moreover, we added another category: habituation to tasks and situations.

The six thought categories for the retrospective verbal report were as follows:

1. Worries/negative thoughts and thoughts regarding the monitoring of the performance (e.g., "I was so panicked because if I failed this task, my partner wouldn't get any rewards", "I'm worried about that video-camera" and "It was replayed in my mind that I have to improve").
2. Thoughts related to the performance of the task (e.g., "I attempted to make a diamond-shaped grid in my mind" and "I memorized the underlined words by connecting meanings to each word").
3. General thoughts related to the situation or task (e.g., "I would do my best" and "It is interesting to perform these tasks").
4. General distress/tension (e.g., "I am tired and sleepy" and "I do not feel clear because it is morning now").
5. Thoughts unrelated to the experiment (e.g., "I wanted to eat more breakfast").
6. Habituation to tasks and situations (e.g., "I am more relaxed now than I was a moment ago" and "I feel accustomed to these tasks because I completed them the first time").

Table 1 The number of thoughts reported in each of the six categories

Thought categories	Condition			
	Baseline		Pressure	
	M	SD	M	SD
1. Worries/negative thoughts	1.73	0.91	2.30	1.33
2. Thoughts related to performing the task	1.23	1.11	0.50	0.81
3. General thoughts related to situations and tasks	0.12	0.33	0.32	0.63
4. General distress/tension	0.12	0.43	0.04	0.20
5. Thoughts unrelated to the experiment	0.15	0.61	-	-
6. Habituation to tasks and situations	0.04	0.20	0.50	0.58

Note: These are the mean numbers of thoughts in each category per participant. There were no data on thoughts unrelated to the experiment under pressured conditions.

The number of thoughts in each category was calculated and their means are shown in Table 1. Two researchers independently coded the thoughts on the retrospective verbal reports. An inter-rater agreement was indexed on the basis of kappa statistics, with a kappa value of < .40 rated "poor", between .40 − .70 rated "acceptable to good", and > .70 rated "excellent"[18]. The kappa values of worries/negative thoughts (baseline = .83; pressure = .76), thoughts related to performing the task itself (baseline = .62, pressure = .76), general thoughts related to the situation or task (baseline = .84; pressure = .72), general distress/tension (baseline = .74; pressure = 1.00), thoughts unrelated to the experiment (baseline = 1.00; pressure = no data), and habituation to tasks and situations (baseline = 1.00; pressure = .71) were considered to have excellent or good agreement. These results supported the inter-rater agreement for the retrospective verbal report.

Paired samples t-tests were conducted to compare the six thought category scores for baseline and pressured conditions. There was a significant difference in the worries/negative thoughts scores for the baseline and pressured conditions, $t\ (25) = 2.26, p < .05$. This result suggests that the participants reported more worries/negative thoughts about the situation and their performance under pressured conditions than they did under baseline conditions, although they did not report subjective pressure under pressured conditions. Therefore, the result of the retrospective verbal report indicated that pressure manipulation was successful in this study. The participants reported more thoughts about performing the tasks under pressured conditions than they did under baseline conditions, $t\ (25) = 3.05, p < .05$. They also reported more thoughts of habituation to the tasks and situations under pressured conditions than they did under baseline conditions, $t\ (25) = 3.63, p < .01$. Although the subjective pressure questionnaire showed no significant difference between baseline and pressured conditions, the retrospective verbal report showed that the participants had more worries and negative thoughts under pressured conditions than they did under baseline conditions.

3.3 Verbal and visuospatial WM task score

A paired samples t-test was conducted to compare the reading span score under baseline conditions with that under pressured conditions. There was no significant difference in the scores for the baseline (M = 7.25; SD = 2.74) and pressured (M = 7.58; SD = 3.16) conditions, t (25) = −0.70, *n.s.* However, in the spatial span score, there was a significant difference between the baseline (M = 10.25; SD = 4.78) and pressured (M = 7.50; SD = 3.97) conditions, t (91) = 3.64, p < .01.

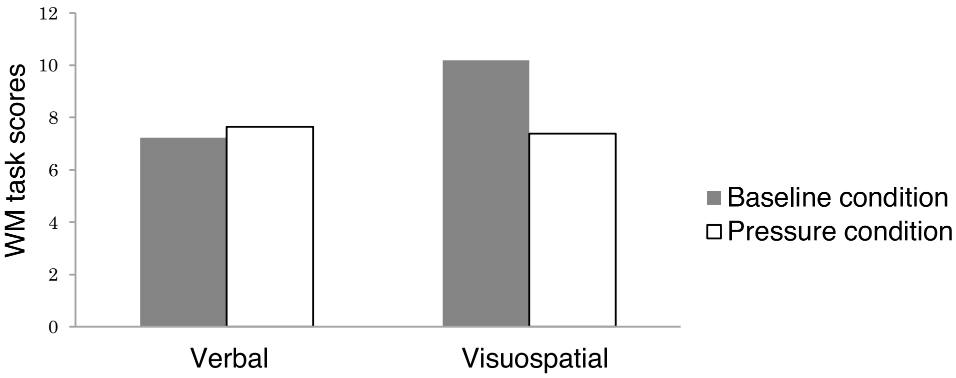

Figure 1 WM task scores under baseline and pressured conditions

4. Discussion

DeCaro et al.[9] assumed that the ruminations of pressure-induced worry/negative thoughts interfered with the verbal aspect of WM because they consist of verbal information. To the contrary, this study assumed that pressure-induced worry/negative thoughts interfere with the central executive aspect of WM. In other words, we predicted that both the verbal and visuospatial WM task performances would decline under pressured conditions. However, our results differed from those of DeCaro et al.[9] and our own predictions. Our results showed that presenting the pressure scenarios decreased visuospatial WM capacity. In the retrospective verbal report, presenting the pressure scenarios increased worry/negative thoughts and decreased thoughts related to performing the task. Although DeCaro et al.[9] used verbal and visuospatial mathematical tasks, we used verbal and visuospatial WM tasks and compared them with WM task performances under baseline and pressured conditions. Our findings serve as direct evidence of the effect of pressure on visuospatial WM capacity. In contrast to DeCaro et al.[9] and our hypothesis, pressure-induced worry or negative thoughts did not affect verbal WM. We posit that the reason behind verbal WM not being affected by pressure-induced thoughts is that the practice effect of reading span was not controlled in this study. The participants were presented with the same sentences but in a different order under baseline and pressured conditions. It is possible for the practice effect on the reading span task to have increased reading span performance under pressured conditions.

Just as this study does, other studies have indicated that situation-induced anxiety selectively disrupts visuospatial WM task performance. Shackman et al.[19] and Lavic et al.[20] investigated the effects of the threat of shock-induced anxiety arousal on verbal and spatial WM task performances (3-back task). Their results showed that the threat of shock-induced anxiety arousal selectively reduced spatial WM task performance but did not reduce verbal WM task performance. Shackman[19] argued that anxiety arousal harmed spatial WM because both anxiety arousal and spatial WM are associated with the right prefrontal cortex. However, Moran[14] has shown that the evidence that anxiety interferes with verbal and visuospatial WM is inconsistent due to differences in anxiety measurement, manipulation to induce anxiety, and the type of

WM task. The disagreement among the previous studies shows that we must carefully consider the effects of pressure on verbal and visuospatial WM.

Although this study has shown that pressure does affect visuospatial WM, the effect of pressure on verbal WM was poorly assessed because of the practice effect of the reading span task. To solve this problem, it would be better to use a verbal WM task of low practice effect, such as operation span[21] and counting span[22]. It would also be appropriate to add a control group for comparison with participant results when they are not presented with pressure scenarios. In addition, there were two problems with the subjective pressure questionnaire and the retrospective verbal report. First, there was the lack of items in the subjective pressure questionnaire. The subjective pressure questionnaire in this study could not capture individual differences on subjective pressure feelings because the questionnaire consisted of only one question. It is necessary to consider other methods of rating subjective pressure, such as adding more questions to the questionnaire. Furthermore, it is necessary to measure the importance of tasks, because pressure is a factor that increases with the importance of a task. Second, the correlation between the two questionnaires and verbal and visuospatial WM remains unclear. The participants in this study rated their sense of pressure and reported their thoughts and feelings only after all conditions were finished. Therefore, it is unclear as to whether the thoughts reported in the retrospective verbal report actually occurred during the verbal WM task, particularly as opposed to the visuospatial WM task, or vice versa. To ascertain the relationship more accurately, it would be better to ask participants to report after each WM task.

References

1. Baumeister RF : Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology*, **46**(3), 610-620, 1984.
2. Beilock SL and Carr TH : On the fragility of skilled performance: What governs choking under pressure. *Journal of Experimental Psychology: General*, **130**(4), 701-725, 2001.
3. Beilock SL : Mathematical performance in stressful situations. *Current Directions in Psychological Science*, **17**(5), 339-343, 2008.
4. Beilock SL, Kulp CA, Holt LE and Carr TH : More on the fragility of performance: Choking under pressure in mathematical problem solving. *Journal of Experimental Psychology: General*, **133**(4), 584-600, 2004.
5. Miyake A and Shah P : *Models of working memory: Mechanisms of active maintenance and executive control*. Cambridge University Press, New York, 1999.
6. Baddeley AD and Hitch GJ : Working memory. *The Psychology of learning and motivation: Advances in research and theory*, **8**, 47-89, 1974.
7. Repovs G and Baddeley A : The multi-component model of working memory: Explorations in experimental cognitive psychology. *Neuroscience*, **139**(1), 5-21, 2006.
8. Shah P and Miyake A : The separability of working memory resources for spatial thinking and language processing: An individual differences approach. *Journal of Experimental Psychology: General*. **125**(1), 4-27, 1996.
9. DeCaro MS, Rotar KS, Kendra MS and Beilock SL : Diagnosing and alleviating the impact of performance pressure on mathematical problem solving. *The Quarterly Journal of Experimental Psychology*, **63**(8), 1619-1630, 2010.
10. Trbovich PL and LeFevre J : Phonological and visual working memory in mental addition. *Memory & Cognition*, **31**(5), 738-745, 2003.
11. Eysenck MW and Calvo MG : Anxiety and performance: The processing efficiency theory. *Cognition & Emotion*, **6**(6), 409-434, 1992.
12. Owens M, Stevenson J, Hadwin JA and Norgate R : Anxiety and depression in academic performance: An exploration of the mediating factors of worry and working memory. *School Psychology International*, **33**(4), 433-449, 2012.

13. Vytal KE, Cornwell BR, Letkiewicz AM, Arkin NE and Grillon C : The complex interaction between anxiety and cognition: Insight from spatial and verbal working memory. *Frontiers in Human Neuroscience*, **7**, 93, 2013.
14. Moran TP : Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin*, **142**(8), 831-864, 2016.
15. Daneman M and Carpenter PA : Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, **19**(4), 450-466, 1980.
16. Osaka M : *Working memory: The sketchpad in the brain*. Shin-yo-sha Corporation, Tokyo, 2002. (In Japanese).
17. Beilock SL and Carr TH : When high-powered people fail: Working memory and "choking under pressure" in math. *Psychological Science*, **16**(2), 101-105, 2005.
18. Fleiss JL, Levin B and Paik MC : The measurement of interrater agreement. In Fleiss JL, Levin B and Paik MC eds, *Statistical Methods for Rates and Proportions*, the second edition, Wiley, New York, 212-236, 1981.
19. Shackman AJ, Sarinopoulos I, Maxwell JS, Pizzagalli DA, Lavric A and Davidson RJ : Anxiety selectively disrupts visuospatial working memory. *Emotion*, **6**(1), 40-61, 2006.
20. Lavric A, Rippon G and Gray JR : Threat-evoked anxiety disrupts spatial working memory performance: An attentional account. *Cognitive Therapy and Research*, **27**(5), 489-504, 2003.
21. Turner ML and Engle RW : Is working-memory capacity task dependent? *Journal of Memory and Language*, **28**(2), 127-154, 1989.
22. Case R, Kurland DM and Goldberg J : Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology*, **33**(3), 386-404, 1982.