EXPLORATION AND EXPLOITATION AS PREDICTORS OF PERFORMANCE DECREMENTS UNDER PRESSURE

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Psychology

2012

ABSTRACT

BREAKING UNDER PRESSURE: EXPLORATION AND EXPLOITATION AS PERDICTORS OF PERFORMANCE DECREMENTS UNDER PRESSURE

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Research has demonstrated that high levels of pressure can cause individuals' performance on complex tasks to decrease. The goals of the current study were to examine the tradeoff between exploratory and exploitative problem-solving strategies as an explanation of performance maintenance or decline under pressure and to employ a metacognitive intervention as a strategy to mitigate the negative effects of pressure on exploration. The current study included 176 undergraduate participants who completed a resource foraging simulation. Results indicated that exploratory strategies led to greater performance in the complex task condition, but exploitative strategies were superior in the simple task condition. The high pressure condition had minor effects on exploratory behaviors. The metacognitive intervention had strong and positive effects on exploratory behaviors, buffering individuals against the negative effects of pressure on performing complex tasks. Individual difference factors and state-orientations were explored as factors impacting the effects of pressure on exploration. Future research and practical implications are discussed for maintaining or declining performance under pressure.

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Introduction

On July 5, 1994, a forest fire broke out on Storm King Mountain in South Canyon, Colorado (Butler, Bartlette, Bradshaw, Cohen, Andrews et al., 1998). The unthreatening, 10-acre fire quickly spread in less than 24 hours to a daunting 1,000 acres with a temperature of 2,500 degrees Fahrenheit and a speed of 30-45 miles per hour (Useem, Cook & Sutton, 2005). An enormous amount of pressure was on the leader, Daniel Mackey, as he was responsible for ensuring the well-being of many lives, surrounding communities and the 49-member fire team. Counter to their standard procedures manual (Incident Operations Standards Working Team, 2002), Mackey ordered his team to build the fire line downhill and he did not check to make sure the area for the line was clear of fire, which it was not. In addition, he failed to request updates on the weather, which had become so severe the team would have understood the severity of the situation and evacuated the mountain. When the team finally realized that the fire was out of control and the intended area for the fire line was ablaze, it was too late. Mackey and 14 members of his crew died. If he had he not ordered the fire line to be built downhill in hazardous terrain, checked to make sure the area for the line was clear or asked for weather updates, his team would have escaped unharmed (Useem et al., 2005). With many lives in his hands and communities at risk, the pressure caused Mackay to severely underperform. Not only did he fail to adequately assess the severity of the situation and optimal courses of action, he acted contrary to basic procedures, leading to the death of 14 firefighters.

In 2001, American Airlines flight 587 took off from JFK airport (Accident Report-Flight 587, 2001) shortly after a much larger Boeing 747 and flew into the larger plane's wake, creating substantial turbulence. First officer Steve Molin attempted to stabilize the plane by aggressively moving the rudder back and forth, but the rudder was not built to be used in this way or withstand such stress. The vigorous back and forth motion caused the stabilizer to tear off, in turn causing the engines to break from the plane. Minutes into the flight, the plane plummeted into Belle Harbor, a New York neighborhood below, killing all 251 passengers, 7 cabin crew members, 2 flight members and 5 bystanders. The National Transportation Safety Board reported that the "unnecessary and excessive rudder pedal inputs" by the First Officer caused the crash (p. 160). More seriously, however, the report also stated that if Molin had done nothing, the plane would have stabilized on its own. Under intense pressure from being responsible for 260 lives, Molin not only failed to adequately assess the problem as innocuous, but reacted unnecessarily and used the rudder in an incorrect manner. His decision making broke down under pressure and his actions brought down the plane and 260 lives.

In contrast to these two situations where performance decrements led to disasters, U.S. Airways flight 1549 leaving from LaGuardia Airport in 2009 does not have a tragic ending (Accident Report-Flight 1549, 2009). Minutes into the flight, the plane came across a flock of birds that went through the turbines and took out the engines. The flight's captain, Chelsey Sullenberger, immediately requested to return to the airport, but by the time he received permission, it was too late. Other options were nearby Teterboro or Newark Airport, but after requesting permission to land at Teterboro, Sullenberger realized that it was not possible and responded "We're unable…we may end up in the Hudson." (Aircraft Accident Transcript, 2009, p. 4). He successfully landed the aircraft in the Hudson river, saving all 155 lives onboard and has been labeled a hero (MSNBC Report, 2009).

These three scenarios have drastically different outcomes, but they all had the potential of being a success or disaster story because small decrements in performance had the potential of producing severe consequences. What were the differences between them? Why did Mackey and

Molin’s performance decline under pressure, while Sullenberger maintained his performance? Sullenberger thoroughly assessed and analyzed the problem situation – he determined that they could not return to LaGuardia, nor land at Teterboro or Newark – which allowed him to choose an optimal course of action. In contrast, Mackey and Molin did not adequately assess the problem and their actions made their respective situations worse. While Sullenberger maintained his focus and effectively dissected the situation, Mackey and Molin’s keen problem-solving skills diminished. High levels of pressure disrupt individuals’ ability to think critically in difficult problem-solving situations (Beilock & DeCaro, 2007). Therefore, experiencing performance decrements on complex tasks, such as flying a plane, fighting fires or making important decisions in organizations, arise because pressure induces individuals to react too quickly, without a proper and effective analysis of the problem and potential solutions. It is an issue of not thinking enough. Performance decrements during a sporting event are the opposite; it is an issue of thinking too much.

Performance decrements under pressure in a sporting context occur when sensorimotor functioning breaks down (Beilock & Carr, 2001). Pressure enhances an athlete’s conscious attention toward their proceduralized actions, which de-automatizes over-learned processes and, in turn, produces inferior performance (Baumeister, 1984; Beilock & Carr, 2001; Lewis & Linder, 1992). Attending to the execution of the step-by-step control found in elite athletic performance causes proceduralized processes, which give rise to unvarying and precise performance, to breakdown (Lewis & Linder, 1997; Masters, 1992).

The current study’s goals are twofold: (1) understand the process of maintaining performance or experiencing performance decrements under pressure when working on complex tasks and (2) mitigate the negative effects of pressure on performing complex tasks. Experiencing performance decrements due to pressure pertain to any work tasks or challenges that require explicit and analytical problem-solving in order to perform at one's optimal level. More importantly, to experience substantial pressure, the individual must perceive (1) the given task to be critical to themselves, others or their organization, (2) their actions as having a direct impact on reaching the task goal and (3) a certain degree of responsibility. Tasks that are perceived as important, present the potential for failure or are impacted by an individual's actions will present a high level of pressure. Tasks or issues that are routine and pose minimal risk of failure are unlikely to produce significant amounts of pressure.

One dominant theory used to explain the negative effects of pressure on performance is explicit monitoring (self-focus; Baumeister, 1984). However, as previously summarized, the theory explains the breakdown in athletic or other sensorimotor-based performance, not the breakdown of effective problem solving strategies. The other most popular theories used to explain performance degradations under pressure are distraction theories, which are based off of limited resources models. Distraction theories posit that anxiety and worry compete with the focus directed toward task execution for limited attentional resources (Beilock et al., 2004; Lewis & Linder, 1997). As individuals' limited resources are directed towards off-task demands such as worry and anxiety, there are fewer resources to direct towards the focal task, which causes performance to decline. Much of the work regarding anxiety as an off-task variable competing for attentional resources comes from academic testing situations in student populations (e.g. Ashcraft & Kirk, 2001; DeCaro, Rotar, Kendra & Beilock, 2010; Tohill & Holyoak, 2000; Wine, 1971), and not professionals within their work domain. When examining professionals performing in their respective domains of expertise, there is substantial evidence indicating that experienced professionals, such as CEOs (McKenzie, Woolf, van Winkelen &

Morgan, 2009), firefighters (Stokes, 1995) and police officers (Storch & Panzarella, 1996), do not experience significant levels of anxiety and worry under stress and pressure. Therefore, it is unlikely that anxiety and worry are the primary causes of professionals experiencing declines in performance when attempting to overcome complex problems within their work environments. Similarly, witness accounts and the flight log indicate that Mackey and Molin were calm and confident, but still underperformed under pressure. Thus, explanations that focus on the experience of anxiety and worry as the primary causes for performance decrements provide an incomplete understanding of the underlying mechanisms of the process.

Additionally, researchers have argued that resource models are theoretically weak, lack testability and scientific merit, and provide little understanding beyond other theories (Allport, 1984; Navon, 1984; Neisser, 1976; Neumann, 1987). Resource models have gained acceptance because, along with their intuitive appeal, they lack the ability to be falsified (Navon, 1984). When examining the theory's hypotheses, only positive evidence is considered relevant, while inconsistent information is "dismissed by resorting to built-in escapes in the theory" (Navon, 1984, p. 231). It is difficult to demonstrate empirically that the theory has made inconsistent predictions because it can always be adjusted to account for negative findings. Therefore, the theory needs additional work in order to generate concrete, falsifiable hypotheses (Navon, 1984).

In its current form, resource theory provides little understanding beyond competing theories (for reviews, see Allport, 1984; Neisser, 1976; Neumann, 1987). For instance, researchers have demonstrated that the central bottleneck of attention theory is better able to explain performance decrements when performing two tasks consecutively (Pashler, 1984) or concurrently (Pashler, 1994). Moreover, other researchers have argued that resource theory does not explain findings from studies using dual-task experiments, which is the main paradigm used to test its hypotheses (Neumann, 1987).

> "Briefly, the problem is that on the one hand interference is usually much more specific than would be predicted on the basis of a limited number of resources, and on the other hand there are cases of quite unspecific interference, that seem not to depend on any specific resource(s) being overloaded" (Neumann, 1987, p.365).

The concept of attentional resources has been argued to be unnecessary to explain current data (for reviews, see Allport, 1984; Neisser, 1976; Neumann, 1987). For instance, using simple and novel tasks, DeShon, Brown and Greenis (1996) examined whether self-regulatory processing requires attentional resources. The tasks were chosen because novel tasks require the regulation of attention, which, according to resources models, will deplete individuals' limited resources. This depletion of resources is posited to lead to decrements in performance on a subsequent task because fewer resources are available to direct attention. In contrast to resources models, DeShon and colleagues demonstrated that having specific and difficult goals, which use more attentional resources than "do your best goals", on the first task led to either no decrements in performance or improvements in performance on the second task. These results demonstrate that self-regulation does not require attentional resources posited by limited resources models. In summary, explicit monitoring and distraction theories provide an incomplete understanding of the process underlying declining performance under pressure while performing complex tasks, and further examination is therefore necessary.

The current study aims to explain the process of maintaining and decreasing performance under pressure using exploration-exploitation theory (e.g. March, 1991; Pyke, 1984). The balance between exploring the problem space for optimal courses of action and exploiting salient options will determine whether individuals are able to handle complex problems under varying levels of pressure. The exploration-exploitation literature will be reviewed, along with how the two strategies of exploring and exploiting apply to performance under pressure. Given that the current study is interested in performance decline during complex tasks, the second section will briefly review factors that contribute to task complexity. The third section will examine the choking under pressure literature and use exploration-exploitation theory to explain past findings. The fourth section will compare the effects of goal-setting and pressure, and demonstrate how they induce similar effects on problem-solving strategies. Finally, the impact of metacognition on performance and the balance between exploration and exploitation will be examined. Metacognitive training will be explored as a training intervention that may help individuals overcome the potential negative effects of pressure on exploratory behaviors and performance.

Exploration and Exploitation

The notion that organisms need to strike a balance between exploration and exploitation has been researched for many decades in different areas such as evolutionary ecology (e.g. Pyke, 1984), psychology (e.g. Voss & Keller, 1983), game theory (e.g. Jervis, 1988), dating and mate selection (e.g. Das & Kamenica, 2005) and organizational sciences (e.g. Gupta, Smith & Shalley, 2006; March, 1991). Exploration includes different behaviors that involve search, variation, risk, experimentation, flexibility, discovery, innovation and learning. In contrast, exploitation includes behaviors that involve refinement of existing skills, production, efficiency, implementation, execution and use of old knowledge (Gupta et al., 2006; March, 1991). Foraging theory (Pyke, 1984; Pyke, Pulliam & Charnov, 1977) portrays the fragile and precarious balance that organisms must maintain between exploration and exploitation in order to survive. Pyke

(1984) provides the example of nectarivores (i.e. animals that eat nectar produced by flowers) who find a patch of flowers and must find the right balance between obtaining nectar from the patch (exploitation) and finding new patches of nectar (exploration). If they choose to only exploit the nectar in the patch, they will not have a set of resources to return to if they are unsuccessful at finding a new patch of flowers, reducing their likelihood of survival. If they choose to only explore for new patches, they will be unsuccessful at harnessing the resources within each patch of flowers, which will also reduce their likelihood of survival.

The proposition that one may perish if they fail to strike a proper balance between exploring and exploiting was extended to organizations by March (1991) in his seminal article. He argued that organizations that focus solely on exploration will incur the costs of experimentation and innovation without gaining many of its benefits because they will possess many undeveloped innovations and little distinctive competence (Levinthal & March, 1993; March, 1991). In contrast, organizations that focus solely on exploitation will become trapped in “suboptimal equilibria” because their systems and technology will eventually approach obsolescence and become uncompetitive (Levinthal & March, 1993; March, 1991). Therefore, in order for organizations to be viable and successful they must balance investment in research and development in order to remain competitive in the future, and maximization of current systems and technology to be competitive in the present. In other words, organizations must balance long-term and short-term benefits (March, 1991); exploration for new innovations reduces the speed at which skills with existing strategy and technology are improved, while improving skills with existing strategy and technology makes new innovation and development less attractive (Levitt & March, 1988).

Despite March (1991) arguing that balancing exploration and exploitation occurs at the individual level and other disciplines focusing on individual organisms (e.g. evolutionary ecology), very little research has examined how this process plays out at the individual level (Laureiro-Martinez, Brusoni & Zollo, 2010). Furthermore, many researchers argue that for organizations to be able to find a healthy equilibrium between exploring new ventures and exploiting old ones, individuals and teams must first be able to find this balance (Beckman, 2006; O'Reilly & Tushman, 2004; Smith & Tushman, 2005). In one of the first articles to analyze this process at the individual level, Mom, van Den Bosch and Volberda (2007) examined exploration and exploitation behaviors in 104 managers at a large international electronics firm. Specifically, they examined managers in the semiconductor division, an area that is highly competitive with intense pressures to both explore and exploit. Overall, they found that managers reported engaging in similar levels of exploration and exploitation activities. However, managers in innovative units (e.g. research and development, marketing and sales) engaged in less exploitation and more exploration activities than managers in the functional units (e.g. production, operations).These preliminary findings indicate that successful managers balance exploration and exploitation, and this balance shifts depending on the needs of their business unit. In other words, the extent to which individuals adopt an exploration and/or exploitation approach is a function of the problem space encountered, with no one strategy being perpetually superior.

When attempting to solve complex and novel tasks, although there may exist several different strategies to overcome the challenge, optimal problem-solving strategies are not immediately apparent or accessible. Exploration of the problem space for optimal strategies will enhance the quality of the adopted problem-solving strategy. Thus, on complex and novel tasks, searching for superior strategies (exploration) will lead to higher levels of performance. In contrast, exploiting simple and immediately available problem-solving strategies will lead to inferior performance because salient strategies are often sub-optimal on novel and complex tasks.

When attempting to solve simple tasks, highly salient strategies are optimal and, therefore, an extensive search for superior strategies may be detrimental because resources are wasted searching for equally viable alternatives. Hence, when approaching simple problems, exploiting salient strategies that are immediately available will lead to superior performance compared to exploring for superior alternatives.

> *H1: Exploratory behaviors will interact with task complexity to predict performance such that exploratory behaviors will positively predict performance on the complex task, but negatively predict performance on the simple task.*

Given that the current study focuses on performance decrements under pressure on complex tasks, the following section will briefly review factors necessary for a task to be considered complex. The subsequent sections will review three areas of research, goal-setting, choking under pressure and metacognition, to demonstrate that high levels of pressure and specific and difficult goals push individuals to adopt exploitation strategies, leading to performance decrements on complex tasks, but higher performance on simple tasks. When individuals experience strong pressure to perform, they are more likely to adopt and vigorously apply (i.e. exploit) salient, heuristic and basic strategies that are suboptimal for complex problems, but optimal for simple tasks. In contrast, low levels of pressure, “do your best” goals and metacognitive activity induce individuals to explore the problem space for optimal strategies, leading to superior performance on complex tasks and inferior performance on simple tasks.

Task Complexity

The current study focuses on the process of decreasing performance under pressure tasks of low and high complexity. Definitions and frameworks of task complexity have been debated for many years (for review, see Campbell, 1988; Wood, 1986). Some researchers argue that task complexity should be assessed with purely objective characteristics (e.g. Schwab & Cummings, 1976; Wood, 1986) because describing a task as a description of behavior or ability requirements simply substitutes the dependent variable for the independent variable of interest, leading to issues of construct validity (Hackman, 1969; Wood, 1986). Wood (1986) argues that task complexity is a function of three factors: component complexity, coordinative complexity and dynamic complexity. Component complexity is defined as a "direct function of the number of distinct acts that need to be executed in the performance of the task and the number of distinct information cues that must be processed in the performance of those acts" (p. 66). Therefore, constructing a building possesses more component complexity than constructing a shelf, as it involves many more distinct acts. Coordinative complexity is defined as "the nature of the relationships between task inputs and task products" (p. 68). It involves the form and strength of the relationships between information cues, inputs and outputs. Thus, assembling a radio involves more coordinative complexity than painting a wall, as acts performed at different stages are contingent upon each other and more highly related. The third type of complexity that contributes to a task's overall complexity is dynamic complexity, which arises from "changes in the states of the world which have an effect on the relationships between task inputs and products" (p. 71). Changes in required behaviors and information cues or relationships between task components can lead to different knowledge and skill requirements for successful task performance. For example, solving an interpersonal conflict possesses more dynamic complexity than greeting an individual, as strategies and tactics may have to shift as individuals' moods change. Therefore, in summary, a task's overall complexity is a function of three interrelated types of complexity. The current study adopts Wood's taxonomy of task complexity and operationalizes task complexity along these three factors.

Goal-Setting: Specific and Difficult versus Do Your Best

Years of research on goal setting has demonstrated that specific and difficult goals direct attention, enhance effort, and increase persistence (for review, see Locke & Latham, 2002). Similar to high levels of pressure, specific and difficult goals inhibit exploration and induce exploitation. Thus, when tasks are basic and immediately salient strategies are optimal, difficult and specific goals produce maximal performance. On complex tasks, which require the exploration for optimal strategies, difficult and specific goals will lead to inferior performance because exploration will be inhibited and salient suboptimal strategies will be exploited. In contrast to specific and difficult goals, do your best (DYB) goals, which have similar effects as low levels of pressure, enhance exploration of the problem-space, leading to performance decrements on simple tasks and maximal performance on complex tasks. Consistent with this, a meta-analytic review demonstrated that specific and difficult goals have strong positive effects on performing simple tasks, but the positive effects are greatly diminished on complex tasks (Wood, Mento & Locke, 1987). This is because complex tasks require exploration and learning of optimal strategies, and specific and difficult goals negatively impact search (Wood et al., 1987) and learning (Seijts & Latham, 2001) processes.

In a series of six studies, Sweller and Levine (1982) examined the effects of having either a specific goal or no goal on learning and problem solving. All six studies used a finger tracing, computer simulated or math maze where the optimal pathway was to initially move away from the end-point. The mazes were constructed in order to make a means-ends strategy suboptimal. A means-ends strategy is where one attempts to directly reduce the discrepancy between one's current state and the desired goal state such as moving directly towards the finish point of the maze. This strategy, the most basic and immediately salient, is adopted by individuals who engage in exploitation while attempting to solve the maze. In all six studies, individuals who received no goal, compared to those with a specific goal, solved the maze in significantly fewer moves. In addition, individuals who did not receive a goal tended to make significantly greater moves in the first quarter of the maze and significantly less in the remaining portion, indicating that they explored the problem space to learn the optimal strategy and, once finding it, used the strategy to perform at a superior level. In contrast, having a specific goal led individuals to exploit the task and adopt a means-ends analysis strategy, which inhibited learning of the optimal strategy for the problem space and, thus, decreased performance. In the final study, the authors constructed a new maze where only half the time a means-ends analysis provided an incorrect decision, and the correct move was always indicated by large arrows. After one practice trial, the no goal group finished the maze in significantly fewer moves than the group that received a specific goal. These studies demonstrate that a specific goal leads to exploitation; it inhibits the search for and learning of optimal strategies, which, in turn, produces inferior performance on novel and complex tasks. DYB goals enhance exploration and improve performance on complex and novel tasks.

In a similar study, Huber (1985) examined the effects of goal setting on performance using a finger-tracing maze task. The task differed in that participants had the option to peek at the maze, but received a substantial time penalty for doing so. Consistent with previous findings, individuals who received a DYB goal completed the maze significantly faster and in fewer moves than individuals who received a specific and difficult goal. More importantly, individuals that received a specific and difficult goal peeked at the maze significantly more often, demonstrating that they were engaging in a means-ends strategy; they were attempting to move straight to the end-point without attempting to search for and learn an optimal problem-solving strategy.

In line with these findings, Vollmeyer, Burns and Holyoak (1996) examined systematic hypothesis-testing as a predictor of learning and performance on a complex biology task that required rule-induction. Consistent with past research, results demonstrated that receiving DYB goals, compared to specific and difficult goals, produced greater learning and performance. In a series of studies, Early, Connolly and Ekegren (1989) examined the effects of goal-setting on performance on a multiple cue probability learning (MCPL) stock market prediction task. They found that receiving a DYB goal led to significantly greater performance compared to specific and difficult goals across multiple trial blocks. More importantly, in their third study they demonstrated that although both goal-setting groups increased their performance over trial blocks, DYB goals led to greater increases over trials compared to specific and difficult goals. That is, there was a greater difference between the goal-setting groups on the third trial compared to the second, indicating that DYB goals lead to the adoption of superior problem-solving strategies, which improve performance over time.

Other researchers have similarly demonstrated that specific and difficult goals, relative to DYB goals, have no significant positive effects on performing complex tasks such as a computer management simulation task (Cervone, Jiwani & Wood, 1991), the MCPL stock market prediction task (DeShon & Alexander, 1996) and an air traffic controller simulation (Kanfer & Ackerman, 1989).

Kanfer and Ackerman (1989) examined the effects of goals on performance using a highly complex air traffic controller simulation. They found that over the 10 performance trials, individuals who first received DYB goals and subsequently received specific and difficult goals at the midway point (i.e. trial 5), performed the better than all other groups. This occurred because DYB goals are initially necessary when the task is novel and complex because task-doers must search for and adopt an optimal strategy, but once an optimal strategy is acquired, exploiting (i.e. vigorously applying) that strategy leads to maximal performance. DeShon and Alexander (1996) found similar results using the MCPL stock market task. In their second study they manipulated the task so that all "individuals relied upon explicit hypothesis generation and testing to learn the task structure" (p. 25). The manipulation caused participants in both the DYB and specific/difficult goal group to engage in exploration and learn an optimal strategy prior to conducting the task. Their results indicated that on the first trial there was no performance difference between the two groups. However, on the second trial the specific and difficult goal group performed better, and the performance discrepancy increased on the subsequent two trials. In line with previous research, this indicates that after participants explore the problem space and adopt an optimal strategy, rather than continuing to explore, exploiting that optimal strategy leads to superior performance. This helps explain why the positive effects of specific and difficult goals only decrease and do not disappear for complex tasks (Wood et al., 1987); on complex tasks, specific and difficult goals can be beneficial if individuals have had time to explore the problem space and thoroughly learn an optimal strategy. Therefore, on novel and complex tasks, an exploratory search for an optimal strategy is necessary.

To summarize, on complex tasks where optimal strategies are not immediately available, DYB goals will produce superior performance because they increase exploration of the problem space and learning of optimal strategies. Specific and difficult goals will produce inferior performance on complex tasks because they will lead to the adoption of immediately salient sub-optimal strategies. Whereas specific and difficult goals are inferior on complex tasks, they produce high performance on simple tasks because optimal strategies are salient and specific and difficult goals will lead individuals to adopt and vigorously apply (i.e. exploit) those strategies. In addition, DYB goals will lead to lower performance on simple tasks because individuals will waste resources searching for equally viable alternative strategies.

Choking Under Pressure

The current study focuses on the process underlying performance decrements under pressure on complex tasks or challenges that require a search for optimal problem-solving strategies. To experience high levels of pressure individuals must feel that maximal performance is critical (Baumesiter, 1984). That is, the amount of performance pressure a task exerts varies as a function of perceived task importance. Challenges that present significant consequences will create high levels of pressure, given that they will be perceived as more important. Pressure manipulations (e.g. Beilock et al., 2004; Markman, Maddox & Worry, 2006) increase the degree of responsibility individuals feel for their performance in order to enhance the pressure individuals experience.

Choking under pressure refers to instances where individuals exhibit significantly inferior performance relative to their own skill level when experiencing pressure, despite working hard and substantial task demands for superior performance (Baumeister, 1984; Beilock & Carr, 2001). In other words, choking under pressure is when an individual greatly underperforms relative to their *own* average level of performance. Simply exhibiting consistently inferior performance is, therefore, not a display of choking. Choking differs from performance decrements because choking implies large drops in performance that lead to failure, whereas decrements represent smaller drops in performance that do not necessarily lead to failure. Studies that examine why individuals' performance declines substantially below their average level of performance provide insights into the underlying mechanisms that lead pressure to impact behavior and performance.

Beilock and colleagues have examined choking (i.e. experiencing performance decrements) under pressure in a series of studies using Gauss' *modular arithmetic* task (as described in Bogomolny, 1996). The task is advantageous because it is not only complex but novel, thus one can be confident that participants have not had prior exposure to the task. It also requires complex rule-based algorithms to solve the problems and, therefore, it cannot be solved using salient and simple heuristic strategies (Beilock et al., 2004). The task involves judging the veracity of problem statements. The problem provides two numbers and a mod, such as $54 \equiv 27$ (mod 3). To do this, participants must subtract the middle number from the first number (i.e. 54 – 27) and divide the difference by the mod (i.e. 18 ÷ 3). If the remainder is a whole number (as here, 6) then the problem is true.

In one of their earliest studies examining performance under pressure using the modular arithmetic task, Beilock and colleagues (2004) had 80 participants complete both low (single-digit problems with no borrow operation) and high (double-digit problems with a borrow operation) demand problems. Individuals underwent three blocks of trials. Half the participants were subjected to either a low-pressure condition where they were not told anything or a high-pressure condition that included a monetary incentive, peer-dependency and social evaluation. First, participants received $5 if they improved their score by 20%. Second, they were told that they had been assigned a partner and they both needed to improve their scores to win, but the partner had already improved his/her score and depended on the participant to improve his/her score in order for both of them to win. Third, participants were told they would be videotaped during the test so that local math teachers and professors could examine their performance. Results found that on the more complex problems, individuals in the low pressure condition improved their performance over trials, while those in the high pressure condition experienced performance decrements. These results demonstrate that on complex problems, instead of exploring the problem space for superior problem-solving strategies, which produces optimal performance, individuals under pressure exploit salient suboptimal strategies, causing them to experience performance decrements. In contrast, under low levels of pressure, individuals increased their performance on the complex problems because they explored the problem space and adopted an optimal strategy. Therefore, high levels of pressure inhibit the exploration for and learning of superior strategies and enhance the exploitation of salient and simple strategies, whereas low levels of pressure induce individuals to explore the problem space and adopt an optimal strategy.

In a second study by Beilock and colleagues (2004), they replicated their results demonstrating that individuals under high (vs. low) levels of pressure experienced significant decrements in their performance. In this second study, half of the participants underwent a substantial amount of practice (i.e. exposed to each problem 49 times) and immediately performed the task under either high or low pressure. Those participants who first practiced the task extensively did not experience performance decrements when performing under pressure. Hence, if individuals are first exposed to a cognitively complex task under low levels of pressure, they engage in exploratory behaviors that allow them find and learn an optimal strategy. When they are subsequently exposed to pressure and induced to exploit their newly learned and available problem-solving strategy that is optimal, they do not experience performance decrements and may even improve their performance because they are exploiting an optimal strategy. Therefore, on novel and complex tasks, high levels of pressure and exploitation strategies will only be beneficial if individuals have had the opportunity to previously explore the problem space and thoroughly learn an optimal problem-solving strategy.

The Beilock et al. (2004) findings were replicated by Ariely, Gneezy, Loewenstein and Mazar (2009), using a field sample from rural India. In the first study they used creativity, memory and motor skills tasks, with incentive levels (low, moderate and high) serving as the pressure manipulation. It is important to note that the sample was from a poor rural area and the high incentive group could earn 400 Rupees, which was close to the average monthly income in the area. Results demonstrated that under high levels of pressure (maximum incentive) performance was substantially lower on all tasks, with performance decrements the greatest for the most cognitively complex task. In their third study, they examined the effects of social pressure (i.e. working in public) on an anagram puzzle task in a sample of 15 American college students. Similar to previous findings, they demonstrated that individuals experienced significant decrements in performance when working under high levels of social pressure compared to when they were working in private under low levels of pressure.

Beilock and Carr (2005) examined individual differences that may give rise to performance decrements under pressure on complex tasks. They utilized the same paradigm as Beilock et al., (2004) with 93 participants to examine the impact of working memory capacity on performance under pressure. Similar to previous findings, results indicated that individuals experienced performance decrements under high, but not low, levels of pressure. More importantly, compared to individuals with low-working memory (LWM), individuals with high-working memory

(HWM) exhibited superior performance on highly demanding tasks under *low* pressure. However, on highly demanding tasks under *high* pressure, individuals with HWM experienced significant performance decrements such that their performance was parallel to individuals with LWM. Therefore, the advantages of HWM when performing complex and demanding tasks disappear when high levels of pressure are present.

These results were replicated by Beilock and DeCaro (2007) using the same paradigm. In a second study they used a water jug task, which requires the use of mathematical reasoning, to examine the mechanisms that cause the advantages of HWM to disappear under pressure. This task is ideal because it is more easily solved by using a simple and salient problem-solving strategy, as opposed to the complex algorithm strategy necessary in the Gaussian arithmetic task. They demonstrated that under low levels of pressure, individuals with HWM used the simple shortcut strategy significantly less compared to individuals with LWM. However, under high levels of pressure there was no significant difference in the mean level of shortcut use between the two groups. Therefore, HWM capacity leads to superior performance on complex tasks because it enables individuals to search for and adopt more complex problem-solving strategies; however, under high levels of pressure, the advantage of HWM capacity disappears because pressure inhibits exploration and induces individuals to adopt salient problem-solving strategies that are suboptimal. This is in line with previous findings demonstrating that high levels of pressure cause individuals to forgo the search for complex strategies, and adopt and exploit basic problem-solving strategies that are immediately salient.

The series of studies conducted by Beilock and colleagues support the current study's propositions that high levels of pressure induce individuals to exploit immediately available and salient problem-solving strategies, which leads to performance decrements on complex tasks where a search for optimal strategies is required. In contrast, low levels of pressure induce exploratory behaviors that lead individuals to search for and adopt optimal strategies and, thus, display superior performance on complex tasks. These propositions are furthered by the findings that HWM individuals exhibit superior performance on complex tasks, but only under low pressure situations where they search for and adopt superior problem-solving strategies that LWM individuals are incapable of learning. When HWM individuals are under high levels of pressure, exploration is inhibited and they exploit immediately salient strategies, and do not exhibit superior performance compared to LWM individuals because both groups are exploiting the similar salient suboptimal strategies. Similarly, on less complex problems, there are no group differences because the most optimal strategies are salient and easily adopted by both groups.

One inconsistency pertains to individuals with LWM. If they do not possess the cognitive ability to adopt complex problem-solving strategies, then exploration will be unhelpful and possibly detrimental if too many resources are expended searching for a strategy they are unable to adopt. Therefore, under high (vs. low) levels of pressure, when they are exploiting salient strategies, they should exhibit greater levels of performance because they are not wasting resources searching for an alternative that they will not be able to adopt. However, in both of Beilock and colleagues' studies (2005, 2007) there was no significant difference in performance between low and high pressure conditions for LWM individuals, despite a non-significant performance improvement under pressure in the 2007 study.

A study conducted by Gimmig, Huguet, Caverni and Cury (2006) supports the above proposition. The authors attempted to replicate Beilock's findings using an analytical reasoning task and one pressure manipulation (i.e. told participants that the task is highly related cognitive ability). Similar to past findings, they found that on this complex and demanding task HWM (vs.

LWM) individuals exhibited superior performance under low levels of pressure. HWM individuals demonstrated inferior performance under pressure such that decrements reduced their performance to levels exhibited by LWM individuals. In contrast to Beilock's findings, but consistent with the current study, the results demonstrated that individuals with LWM exhibited greater performance under high (vs. low) levels of pressure. This occurred because individuals with LWM are less able to adopt complex strategies discovered by searching the problem space. Thus, for LWM individuals, exploiting immediately available strategies is optimal when superior strategies are too complex for them to acquire efficiently, making exploration a waste of resources. These findings demonstrate that if an individual is not able to find or adopt a complex problem-solving strategy through exploration, such as individuals with LWM capacity, exploiting current and salient strategies produces superior performance.

Ariely and colleagues (2009) demonstrated that when the most optimal strategy is immediately salient, exploitation leads to superior performance. They examined the effects of monetary pressure on performing one cognitive (complex adding) and one physical (key pressing) task. On the physical key pressing task, where optimal strategies are salient and require no exploration, participants improved their performance when experiencing an increase from low to high pressure. Conversely, on the cognitive task, where exploration is necessary to discover optimal strategies, participants performed worse under high, compared to low, pressure. The results demonstrate that exploitation, induced by high levels of pressure, is superior on simple tasks because optimal strategies are immediately available, whereas exploration is superior on complex tasks where optimal strategies are not salient and a search is necessary.

Providing further evidence that the balance between exploration and exploitation strategies depends on the task's problem space (i.e. complexity), Markman and colleagues (2006) examined the effects of Beilock's pressure manipulations on performing two different tasks. The first involved learning and using explicit rules, while the second involved integrating information at an implicit level. On the complex, explicit rule-based task, individuals under low levels of pressure performed significantly better than individuals under high levels of pressure. In contrast, on the more simple information-integration task, individuals under low levels of pressure performed significantly worse than individuals under high levels of pressure. Similar to the research reviewed, these findings indicate that when approaching complex tasks exploration leads to superior performance and exploitation leads to inferior performance.

Although these studies framed the performance declines as *choking* under pressure, the phenomena should be framed as performance *decrements* under pressure because (1) most of the studies utilized between-subjects designs that are not in line with the within-person choking theory and (2) the declines in performance that were observed were often not very large, representing small decrements that hinder performance rather than severe breakdowns in performance that lead to failure. Consistent with the study's propositions, the choking literature supports the notion that when performing complex tasks, decrements in performance occur when pressure induces individuals to inhibit exploration and exploit prematurely. Exploration of the problem space is necessary when a task is novel and complex because one must find an optimal strategy and disregard immediately salient strategies that are inferior. However, when tasks are simple, exploitation of immediately available strategies is superior because salient and available strategies are optimal for basic tasks. High levels of pressure, which have similar effects as specific and difficult goals, inhibit exploration of the problem-space and enhance exploitation of salient and available problem-solving strategies. In contrast, given the current boundary condition that tasks possess a basic element of importance to the task-doer, low levels of pressure, which have similar effects as DYB goals, enhance exploration of the problem space.

H2: Pressure will negatively predict exploratory behaviors such that high levels of pressure will be associated with low levels of exploratory behaviors and low levels of pressure will be associated with high levels of exploratory behaviors.

Metacognition

Similar to DYB goals are mastery goals, which focus on developing one's knowledge and competence (Dweck, 1986; Elliot, 1999). Mastery goals are similar to DYB goals and low pressure situations, as they induce exploration of the problem space, which is why they enhance learning and performance (Smith, Ford & Kozlowski, 1997). For example, mastery goals in children have been shown to lead to the adoption of more effective learning strategies (Ames & Archer, 1998). Additionally, using adult samples and a complex radar tracking simulation, researchers have shown that mastery goals enhance knowledge acquisition and performance (Bell & Kozlowski, 2008; Ford, Smith, Weissbein, Gully & Salas, 1998; Kozlowski, Gully, Brown, Salas, Smith & Nason, 2001). However, this relationship is not direct; there is evidence that mastery goals increase learning and performance through the enhancement of metacognitive activity (Bell & Kozlowski, 2008).

Metacognition includes awareness and control over self-monitoring and self-regulatory processes (Leonesio & Nelson, 1990), the engagement in mindful and deliberate learning (Smith, Ford & Kozlowski, 1997), and the ability to utilize cognitive strategies (Bereiter & Scardamalia, 1985). Many researchers have demonstrated that greater metacognitive skills lead to improved performance (Bell & Kozlowsi, 2008; Elio & Anderson, 1984; Ford, Smith, Weissbein, Gully, & Salas, 1998; Volet, 1991). Metacognition has a positive effect on performing complex tasks because it facilitates exploratory behaviors, such as planning and strategy search (Smith, Ford & Kozlowski, 1997). Therefore, greater metacognitive activities enhance exploration by allowing individuals to more easily discover and learn optimal strategies (Ford et al., 1998; Bell & Kozlowski, 2008).

Schmidt and Ford (2003) induced metacognitive activity by providing knowledge of the importance and effects of metacognition, knowledge of how to engage in metacognitive processes, and self-reflection strategies. Metacognitive interventions not only enhance metacognitive activity, but they lead to greater learning and performance (Schmidt & Ford, 2003; Short & Ryan, 1984). Therefore, interventions that enhance metacognitive activity will lead to greater learning and performance.

Bell and Kozlowski (2002) demonstrated the link between metacognition, learning and performance using a complex radar tracking task (TANDEM). Individuals underwent either a metacognitive or descriptive training. The metacognitive training intervention involved adaptive guidance, which provides trainees with strategies to make effective learning decisions. The control group received a learner-control focused training, which involved descriptive feedback only. The authors found that the metacognitive, compared to the learner-control, training led to enhanced basic and strategic knowledge and performance. Thus, the findings indicate that enhanced metacognitive activity leads to greater learning and performance on complex tasks.

Similar to the findings demonstrating that once an optimal strategy is acquired, exploitation is the optimal strategy, researchers have shown that after receiving metacognitive training (i.e. taught to explore of the problem space), specific and difficult goals lead to optimal performance outcomes. For instance, Early, Connolly and Lee (1989) provided participants with one of two metacognitive training interventions prior to performing an MCPL stock market task. The first group received strategy domain restriction training (i.e. given a short list of possible strategies and taught how to use them), the second group received strategy development training (i.e. given a guide on how to find the best strategy) and the control group received no training. Results demonstrated that individuals who received either metacognitive training and specific and difficult goals displayed greater performance compared to individuals with (1) specific and difficult goals and no metacognitive training, (2) DYB goals without training and (3) DYB goals with either metacognitive training. This is similar to DeShon and Alexander (1996), who demonstrated that after receiving an intervention that enhanced metacognitive activity (i.e. they forced participants to rely on explicit hypothesis generation and testing strategies to learn the task structure), individuals with specific and difficult goals outperformed individuals with DYB goals. Therefore, these studies demonstrate that after undergoing metacognitive training and exposure to the task, which allows individuals to explore for and learn an optimal strategy, individuals who exploit their current optimal strategy exhibit greater performance.

Using a complex biology task that requires rule induction, Vollmeyer et al. (1996) conducted a second study in which half of the participants in each goal group received metacognitive skills training (i.e. taught the optimal strategy for the task). Results showed that participants who received the training outperformed those who did not receive the training. However, receiving specific and difficult goals caused individuals to abandon the optimal strategy taught during training for an inferior difference-reduction (i.e. means-end, exploitation) strategy, leading to decrements in performance. This most likely occurred because the intervention did not allow for thorough learning of the optimal strategy, and when individuals were induced to exploit, a suboptimal strategy was more salient than the poorly learned optimal one.

Although specific and difficult goals can enhance performance on novel and complex tasks if they lead to the exploitation of an optimal strategy, they substantially decrease performance if they cause individuals to apply a basic and sub-optimal problem-solving (i.e. means-ends) strategy. Thus, exploitation on complex and novel tasks will only be beneficial if individuals first search the problem space and adopt an optimal problem solving strategy, and then subsequently exploit the newly acquired optimal problem-solving strategy. In addition, the acquired strategy must be thoroughly learned such that it is more salient and ingrained than more basic and simple sub-optimal strategies. Therefore, metacognitive interventions that train individuals to explore a problem space will buffer against the effects of high pressure to exploit the problem space. Such interventions will decrease the extent to which pressure inhibits exploration and allow individuals to learn an optimal strategy, and perform at a high level.

When high levels of pressure are present, individuals who undergo an intervention that enhances metacognition will explore the problem space more than individuals who do not receive the intervention. Thus:

H3: Under high levels of pressure, individuals who receive the intervention will exhibit greater exploratory behaviors compared to individuals who did not receive the intervention.

H4: Task complexity will interact with the metacognition intervention such that the intervention will lead to greater performance on the complex task and lower performance on the simple task, whereas high pressure with no metacognitive intervention will lead to greater performance on the simple task and lower performance on the complex task.

The hypothesized relationships are summarized in figure 1. Examining the model, pressure impacts performance through its effects on exploration/exploitation, and task complexity moderates both the relationship between pressure and exploration/exploitation, and exploration/exploitation and performance.

Individual Difference Factors

Individual difference factors that influence an individual's likelihood of exploring a problem space will impact the proposed relationships. The constructs that are the most pertinent to the process of exploring and exploiting under pressure are Mastery Orientation, Avoid-Performance Orientation and working memory. These individual difference factors will be discussed and their effects on the proposed relationships will be hypothesized.

Goal Orientation

Goal orientations are motivational processes that impact learning and performance on cognitive tasks (Dweck, 1986; Dweck & Leggett, 1988). Mastery (learning) goal orientation refers to the tendency to seek increases in competence, understanding or mastery of a new challenge (Dweck, 1986). Individuals with a high mastery orientation tend to explore and pursue tasks that promote intellectual growth (Dweck, 1986). Researchers have separated Dweck's performance orientation into prove-performance and avoid-performance orientations (VandeWalle, 1997; VandeWalle, Cron & Slocum, 2001). Prove-performance orientation is the tendency to seek favorable judgments about one's competence, whereas avoid-performance orientation is the tendency to avoid disproving one's competencies and avoid potential unfavorable judgments concerning one's competencies (VandeWalle, 1997; VandeWalle et al., 2001). Research has demonstrated that mastery orientation is positively related to learning and performance (Dweck, 1986; VandeWalle et al., 2001) and avoid-performance orientation is negatively related to learning and performance (VandeWalle et al., 2001).

H5a: Mastery orientation will be positively related to exploratory behaviors.

H5b: Mastery orientation will interact with the metacognition intervention to predict exploratory behaviors such that the intervention will increase exploratory behaviors more for individuals low, compared to high, in mastery orientation.

H5c: Avoid-performance orientation will be negatively related to exploratory behaviors.

H5d: Avoid-performance orientation will interact with the metacognition intervention to predict exploratory behaviors such that the intervention will increase exploratory behaviors more for individuals high, compared to low, in avoid-performance orientation.

Working Memory

Working memory refers to the capacity to store and manipulate information for brief periods of time (Alloway, 2009). It has been shown to be positively related to learning (Alloway, 2009), mental arithmetic (DeStefano & LeFevre, 2004) and reading span (Conway, Kane, Bunting, Hambrick, Wilhelm & Engle, 2005). Importantly, researchers have demonstrated that individuals with high working memory capacity explore problem spaces more, and acquire and apply superior strategies than individuals with low working memory capacity (Beilock & DeCaro, 2007; Gimmig et al., 2006). Given that exploratory learning increases the cognitive workload (Tuovinen & Sweller, 1999), individuals with low working memory may be less able or willing to explore because the complexity of an extensive search would severely tax their already limited cognitive capacity (van Merrienboer, Kirschner & Kester, 2003). Therefore, they may not only struggle to explore effectively, but they may also not reap the benefits of a costly exploration. In line with this, research has shown that exploration enhances learning more for individuals with high, compared to low, cognitive ability (Gully, Payne, Koles & Whiteman, 2002), which is nearly indistinguishable from working memory (Colom, Abad, Rebollo & Shih, 2005; Colom, Rebollo, Palacios, Juan-Espinosa & Kyllonen, 2004; Engle, Tuholski, Laughlin & Conway, 1999; Stauffer, Ree & Carretta, 1996).

H6a: Individuals with high working memory will engage in more exploratory behaviors than individuals low in working memory capacity.

H6b: Working memory will interact with the metacognition intervention to predict exploratory behaviors such that the intervention will increase exploratory behaviors more for individuals with low, compared to high, in working memory.

Method

Participants

The original sample consisted of 184 undergraduate students from Michigan State University. Thirty-eight percent were male, 71.8% were Caucasian, 5.4% were African-American, 12.1% were Asian and the remainder of the sample consisted of Hispanic, Latino, Hawaiin or other Pacific Islander, American Indian, multi-ethnic and other. The mean age was 21 (*SD* = 1.89). Data was collected in a one-hour laboratory session. Students received course credit for their participation. Participants' data was removed if they did not complete all five simulation trials. The final sample consisted of 176 participants.

Task: Foraging Simulation

The experiment was a 2 (simple vs complex task) X 3 (low pressure, high pressure, high pressure with the metacognition intervention) between group design. It is important to note that there is no low pressure group that receives the intervention. Participants were assigned to either the low pressure (control), high pressure or high pressure with the metacognitive intervention condition, and they performed either the simple or complex task. Prior to the experimental trials, participants received a brief training on the task (approximately 5 minutes). The training informed them of what the simulation would consist of (e.g. number of trials), and how to move around the world and collect resources (e.g. world size, total value of world's resources, move delays, etc). The arrow keys allowed participants to move around the world, which was a grid map 30X30 blocks large. Participants saw an aimer on the screen, which they moved around from block to block using the arrow keys on the keyboard. Resources were smaller squares located within each block on the grid map. Red resources were worth 1 point and there were 16 red squares within a block, whereas yellow resources (pressure condition only) were worth 25 points and there were 4 squares located within a block. Red resources were randomly scattered all over the world, whereas yellow resources were placed far from the starting point. There was a .3 second move and collection delay. The space bar was used to pick up resources. That is, once the aimer was moved over top of a resource, pushing the space bar collected the resource and turned the square black. Participants were told that there was close to 3000 points in the entire world. It is important to note that participants had a restricted field of view such that they could only see nine blocks at any one time. Participants were told the goal was to collect as many resources as possible. Participants were also told the move and collection delay and size of the world. The training was uniform across conditions. Participants engaged in two one-minute practice trials in order to be sure that they knew how to move and collect resources properly. Participants in the intervention condition underwent the metacognitive training immediately prior to the task training. After the practice trials, all participants underwent 5 trials of 5 minutes each. After completing the simulation, participants completed self-report measures.

Manipulation

The high pressure scenario involved peer pressure and social evaluation. Most studies examining the effect of pressure on performance include peer pressure and social evaluation as a pressure manipulation (e.g. Beilock et al., 2004; Markman et al., 2006). Although many of the studies also include monetary incentives, Gimmig and colleagues (2006) replicated Beilock and colleagues' findings using only social evaluation as a pressure manipulation. Participants performed the task in a room of 4 to 8 participants. Outside of the laboratory was a large sheet of paper with each participant's name and their score, ordered highest to lowest for the entire team. Participants were told that they would be working independently, but their scores would all be added together to create a team score. They were informed that the team score and each individual participant's score would be posted outside the laboratory after the experiment. They were told to do their best and that the goal was to achieve the highest possible score.

Individuals in the low pressure scenario were told the maximum possible points and that the goal is to achieve the highest score possible.

Pressure Manipulation Check:

Participants were asked to respond how much they agreed with the following statement "During the simulation I felt pressure to perform" using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Metacognitive Intervention

The metacognitive intervention was modeled after Schmidt and Ford's (2003) intervention. The intervention taught participants about metacognition and how to increase their metacognitive activity through self-questioning. For example, participants were told to ask themselves about the parameters of the game and what they needed to do to collect the most valuable resources. The intervention took approximately 5 minutes. Participants were given a list of questions to ask themselves during and between trials. See Appendix C.

Complexity

In line with Wood's (1986) definition of task complexity, the complex task condition enhanced component and coordinative complexity. In the complex task condition yellow resources that are valued 25X greater than the red resources are added to the map in remote locations. This enhances component complexity because it adds another act (i.e. searching) that must be executed. Moreover, individuals must move around the map differently in the complex task in order to use their time as efficiently as possible. When searching they must not move through blocks that contain red resources that will not be collected because they will have to travel across each of the four resource squares, which takes four times as long to move through than a single block without any resources. The must move around blocks with unwanted resources in order to move more quickly throughout the map. Moreover, the addition of yellow resources provides another information cue, adding to the component complexity. Coordinative complexity is also enhanced because the form of the relationship between information cues and inputs changes, and behaviors early in the task impact behaviors later in the trial. Specifically, behaviors early on in a trial impact behaviors later in a trial because if individuals exploit for the first half of the trial, they will not have sufficient time to thoroughly search the map and discover the more valuable resources. Dynamic complexity was not manipulated in either task condition.

Measures

State goal orientation. Participants completed three scales assessing state goal orientation (see Bell & Kozlowski, 2008). The scale treats mastery, prove-performance and avoid-performance orientations as distinct constructs from VandeWalle's (1997) trait measure of goal orientation. Items were rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Mastery orientation was measured using four items ($\alpha = .82$), prove-performance was measured using five items (α = .86) and avoid-performance was measured using four items (α = .55). Please see Appendix C for scales.

Anxiety. State anxiety was measured using the State-Trait Anxiety Inventory (Spielberger, 1983). The scale consists of 20 items (α = .70) rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The STAI has demonstrated good convergent and discriminant validity (e.g. Spielberger, 1989).

Working Memory. The Operation Span (OSPAN; Turner & Engle, 1989) was used to assess working memory. During the assessment, participants were exposed to a simple math equation (e.g. IS (3 x 1) + 1 = 5 ?) that includes an answer that is either correct or incorrect. The participant must first read the equation and circle "YES" if the answer is correct and "NO" if the answer is incorrect. The participant is then shown a word (e.g. DOG) on the next slide, which they must read silently. The participant is then shown another equation-word pair. Each round consists of two to six equation-word pairs. At the end of the round participants must recall the words from the entire round and write them down. The task consists of 9 trials. In order for the task to be scored, participants must have had at least 85% of the equations correct. Consistent with many studies, no data was thrown out of the final sample. The task was scored using two methods. The first method awards one point for each correctly recalled word in any order. The second, more stringent method, awarded participants points for every correctly recalled word, but only for those rounds where all words were recalled in the correct order. The results did not differ depending on the scoring method used. Therefore, unless otherwise stated, all results reported regarding working memory will be from the first scoring method, as it is the most widely used.

Exploration and Exploitation. An index was created that combined the number of moves made (i.e. the number of times an arrow key was pressed) and the number of pools encountered but not collected (i.e. the number of blocks with resources inside that came into the participant's field of view). The two scores were standardized before combining. Exploratory and exploitative behavior is represented as a unidimensional construct that lies on a continuum ranging from low (high) exploration (exploitation) to high (low) exploration (exploitation).

Analytical Approach

Two separate multiple regressions were used to test the study's hypotheses; the first used performance as the dependent variable and the second used exploratory/exploitative behaviors as the dependent variable. The two categorical variables, task and pressure, were dummy coded. For the task, the first dummy code was a 1 for complex (complex). Thus, the simple task served as the referent group. For the first dummy code for the pressure variable, a 1 served as low pressure (low pressure) and 0 otherwise. For the second dummy code, a 1 served as high pressure plus metacognitive intervention (high pressure with the metacognitive intervention) and 0 otherwise. Thus, the high pressure condition served as the referent group.

Results

Table 1 presents the means, standard deviations and intercorrelations of the study variables. It is interesting to note that mastery is positively correlated with both avoid-performance and prove-performance ($r = .18$ and $r = .31$, respectively). However, consistent with hypotheses, anxiety is negatively related to mastery ($r = -.18$), but positively related to avoid-performance and prove-performance ($r = .33$ and $r = .28$, respectively). Given that gender appeared to be related to several variables, albeit nonsignificantly, it was entered in as a control into all models.

In order to test whether participants experienced more pressure under the high pressure versus the low pressure condition, a regression was conducted where pressure experienced was entered as the DV and low pressure was entered as the IV; this compares the low pressure group to both the high pressure groups combined. The results demonstrated that individuals in the high pressure groups (*Mn* = 2.76) reported experiencing significantly more pressure than individuals in the low pressure group, $b = -.36$, $\beta = -.17$, $t(152) = -2.20$, $p < .05$. In summary, these results appear to indicate that the pressure manipulation had an effect on the amount of pressure experienced. A similar regression was conducted with anxiety as the DV. The results demonstrated that the groups did not significantly differ $F(2, 137) = .60$, $MSE = .37$, $p = .55$. This is in line with research that demonstrates that anxiety is not the underlying mechanism that causes pressure to negatively impact performance.

Hypothesis 1 states that exploratory behaviors would interact with task complexity to predict performance such that exploratory behaviors would positively predict performance on the complex task, but negatively predict performance on the simple task. Exploration and complexity were entered as predictors in step 2, and exploration X complex was entered in step 3. Score was entered as the dependent variable. The main effects model (step 2) was significant, $R^2 = .43$, $F(3, 151) = 40.55$, $MSE = 43276.33$, $p < .05$. Examining table 2, it appears that exploration and task complexity exerted direct effects on performance. These main effects were qualified by a significant interaction, $\Delta R^2 = .01$, $F(4,150) = 31.11$, $MSE = 42997.63$, $p < .05$. Examining the interaction plotted in Figure 2, it appears that in the complex task condition exploratory behaviors positively predict scores, whereas in the simple task condition exploratory behaviors negatively predict scores. Therefore, hypothesis 1 is fully supported.

Hypothesis 2 stated that pressure would negatively predict exploratory behaviors and Hypothesis 3 stated that under high levels of pressure individuals who received the metacognitive intervention would exhibit greater exploratory behaviors than individuals who did not receive the intervention. To test both hypotheses low pressure and high pressure with the metacognitive intervention were entered as IVs and Exploration was entered as the DV. The overall model was significant, $R^2 = .07$, $F(3, 151) = 5.10$, $MSE = .33$, $p < .05$. Although exploration was greater for individuals in the low compared to high pressure group, the difference was not significant, $b = .13$, $\beta = .10$, $t(145) = 1.08$, $p = .28$. Therefore, hypothesis 2 is not supported. Individuals in the high pressure condition who received the intervention demonstrated significantly greater exploratory behaviors compared to those who did not receive the intervention under pressure, $b = .34$, $\beta = .27$, $t(151) = 3.45$, $p < .05$. These results support Hypothesis 3.

Hypothesis 4 predicted that task complexity would interact with the metacognitive intervention such that the intervention would lead to greater performance on the complex task and lower performance on the simple task, whereas high pressure with no metacognitive intervention would lead to greater performance on the simple task and lower performance on the complex task. To test this hypothesis low pressure, high pressure with the metacognitive intervention and complex were entered as predictors in the first step. Complex X low pressure and complex X high pressure with the metacognitive intervention were entered in the second step. The overall main effects model was significant, $R^2 = .31$, $F(4, 150) = 17.77$, $MSE = 53371.35$, $p < .05$. Task complexity and the metacognitive intervention exerted direct effects on performance. Regression coefficients are presented in table 3. These findings are qualified by a significant interaction between the metacognitive intervention and task complexity, $\Delta R^2 = .01$,

$F(6, 148) = 12.08$, $MSE = 53514.39$, $p < .05$. The nature of the interaction was further explored by plotting the simple slopes in figure 3. Consistent with hypothesis 4, on the complex task, individuals who received the intervention exhibited higher scores compared to those who did not receive the intervention. Contrary to hypotheses, scores did not differ much between groups in the simple task condition. Therefore, these findings provide partial support of hypothesis 4.

Hypothesis 5a stated that mastery orientation positively predicts exploration. Mastery was entered as the IV and exploration was entered as the DV. The overall model was significant, $R^2 = .03$, $F(2, 147) = 7.17$, $MSE = .27$, $p < .05$. The regression coefficients for Mastery were $b = .14$, $\beta = .16$, $p < .05$. Therefore, as mastery orientation increased during the simulation, exploration behaviors increased. These findings supported Hypothesis 5a.

Hypothesis 5b stated that mastery orientation would interact with the metacognitive intervention to predict exploration such that the intervention would increase exploratory behaviors more for individuals low, compared to high, in mastery orientation. Mastery, low pressure and high Pressure with the metacognitive intervention were entered in step 1, and mastery X low pressure and mastery X high pressure with the metacognitive intervention were entered in step 2. Table 4 presents the regression coefficients for each step. The overall main effects model was significant, $R^2 = .11$, $F(4, 145) = 7.51$, $MSE = .25$, $p < .05$. State mastery orientation and the metacognitive intervention exerted direct effects on exploratory behaviors. However, these findings are qualified by a significant interaction, $\Delta R^2 = .05$, $F(6, 143) = 6.76$, $MSE = .23$, $p < .05$. Examination of figure 4 indicates that, contrary to hypothesis 5b, the metacognitive intervention enhanced exploratory behaviors much more for individuals high, compared to low, in state-mastery. Moreover, it appears that mastery had a minimal effect under pressure when the intervention was not present.

Hypothesis 5c stated that avoid-performance orientation would be negatively related to exploratory behaviors. Avoid-performance was entered as the IV and Exploration was entered as the DV. The overall model was significant, $F(2, 149) = 2.99$, $MSE = .35$, $p = .05$, accounting for .4% of variance ($b = .06$, $\beta = .06$, $t(149) = .80$, $p = .43$). Thus, Hypothesis 5c was not supported, as avoid-performance positively predicted exploratory behaviors.

Hypothesis 5d stated that avoid-performance orientation would interact with the metacognition intervention to predict exploratory behaviors such that the intervention would increase exploration more for individuals high, compared to low, in avoid-performance orientation. The regression coefficients are presented in Table 5 for each step. The main effects model was significant, $R^2 = .09$, $F(4, 144) = 6.12$, $MSE = .26$, $p < .05$). The metacognitive intervention was significantly related to exploration. However, these main effects are qualified by a significant interaction, $\Delta R^2 = .08$, $F(6, 142) = 6.68$, $MSE = .24$, $p < .05$. Figure 5 explores the nature of the interaction. Consistent with hypothesis 5d, individuals high, compared to low, in state avoid-performance exhibited higher exploration when receiving the intervention, but lower exploration when not receiving the intervention.

Hypothesis 6a stated that working memory would be positively related to exploratory behaviors. WM was entered as the IV and Exploration as the DV. The overall model was significant ($F(2,150) = 3.62$, $MSE = .35$, $p < .05$) and working memory ($b = .01$, $\beta = .10$, $t(150) = 1.27$, $p = .21$) accounted for 1% of the variance.

Hypothesis 6b stated that working memory would interact with the intervention to predict exploratory behaviors such that under high levels of pressure the intervention would increase exploration more for those low, compared to high, in working memory. The regression results are presented in Table 6. The overall main effects model was significant, $R^2 = .08$, $F(4, 148) = 4.65$, $MSE = .33$, $p < .05$). These results are qualified by a significant interaction, $\Delta R^2 < .01$, $F(6, 146) = 3.07$, $MSE = .33$, $p < .05$. Examining Figure 6, it appears that the intervention had a strong effect for both individuals with high low and high working memory. However, contrary to hypothesis 6b, individuals high in working memory appeared to benefit more from the intervention than individuals low in working memory.

Supplemental analyses

To further investigate mechanisms underlying the relationship between pressure and exploration, I examined the effects of the three pressure conditions and the two task complexity conditions on state anxiety and state goal orientations. None of the relationships were significant at the .10 level. Therefore, given that the first step in a mediation process is for the predictors to be related to the mediating variable (Baron & Kenny, 1986), further investigation was not possible.

Prove-performance state orientation was examined in a similar fashion to avoid-performance. Prove-performance did not significantly predict exploratory behaviors, $F(2,150) = 2.75$, $MSE = .35$, $p = .07$. A second regression was conducted to examine the interaction between prove-performance and pressure condition. Results from each step of the regression are presented in Table 7. The main effects model (step 2) was significant, $R^2 = .06$, $F(4, 148) = 3.75$, $MSE = .33$, $p < .05$. These results are qualified by a significant interaction, $\Delta R^2 = .02$, $F(6, 146) = 3.04$, $MSE = .33$, $p < .05$. Examining figure 7, it appears that individuals low in prove-performance demonstrated similar levels of exploration across pressure conditions, with those under high pressure exploring the least. Individuals high in prove-performance exhibited varying levels of exploration; while individuals under low levels of pressure did not change, those who received the intervention under high pressure exhibited the highest amount of exploration and those under high pressure who did not receive the intervention exhibited the least amount of exploration.

A post-hoc analysis was conducted in order to validate the metacognitive intervention and demonstrate that the intervention had an effect due to increased metacognitive activity. Examining scores across the five trials, the high pressure and the high pressure with metacognitive intervention groups did not significantly differ. Please see table 8 for means and standard deviations. When examining changes in scores between trials, an interesting pattern emerged. Although the two groups displayed similar scores in trial 1 and 5, individuals who received the intervention tended to make significant increases in performance one trial sooner. That is, the high pressure with the metacognitive intervention group significantly increased their scores in trial 2 and trial 4, while the high pressure group increased their scores in trial 3, albeit non-significantly, and trial 5. Please refer to table 11 for these results.

Similar analyses were conducted using exploration as the dependent variable. As can be seen in Table 10, the high pressure group and the high pressure with intervention group significantly differed in exploration on all trials, but trial 2, with the intervention group consistently exhibiting greater exploration. It is interesting to note that neither group significantly increased or decreased their exploratory behaviors across trials. Please see Table 11 for these results. Examining these findings, it appears that the intervention group may have learned the task more quickly, as they increased their scores in earlier trials. However, in contrast to this notion, neither group changed their level of exploration. Thus, these results do not provide strong evidence that the metacognitive intervention had positive effects due to greater metacognitive activity and learning. It is interesting to note that on trials where the two groups did not differ in scores, there was a significant difference in the level of exploration. Therefore, it is possible that the group who received the intervention tended to over-search on average, while the no intervention group tended to under-search on average, leading both groups to achieve similar scores on 3 of the 5 trials.

Discussion

The major goals of the study were to examine (1) the effects of pressure on exploratory behaviors and performance on tasks of varying complexity and (2) methods to decrease the influence of pressure on exploration. Using exploitation and exploration, goal-setting and choking under pressure theory, I proposed that, by inhibiting exploratory behaviors, pressure negatively predicts performance on complex tasks and these negative effects can be mitigated by a metacognitive intervention. Several hypotheses were supported.

Complexity and Exploration

One of the study's main propositions was supported; individuals must balance exploration and exploitation strategies and shift the balance according to a task's difficulty. When individuals underwent the complex task, exploration led to greater scores, but when individuals underwent the simple task, exploration led to lower scores. These findings fit with current literature and support the notion that for individuals to be successful, they must consider their task and correctly balance different exploratory and exploitative problem-solving strategies. It is important to keep in mind that exploratory strategies are not always beneficial and exploitative strategies are not always detrimental. Individuals must continually analyze their situation, understand which type of strategy is more useful at a given moment and recognize the need to switch strategies in order to optimally perform.

Pressure and Exploration

Another of the study's main propositions, namely that pressure negatively impacts exploration, received only partial support at best. Individuals in the low pressure condition exhibited greater exploratory behaviors than individuals in the high pressure condition, but the difference was not significant. Moreover, individuals in the high, versus low, pressure condition reported experiencing greater levels of pressure, but again, the difference was not significant. When comparing individuals in the low pressure condition to individuals in both the high pressure conditions combined, there was a significant difference between the two groups. There are several possible reasons for the minor pressure effects. First, the pressure manipulation only involved social pressure, whereas many studies examining the effects of pressure on performance tend to use multiple forms of pressure simultaneously (e.g. Beilock et al., 2004; Beilock & DeCaro, 2007). Second, individuals' performance did not directly affect other supposed team members' performance. Therefore, some individuals may have felt that their own performance would not greatly affect the team. Third, individuals were told that their scores would be posted after the lab session was complete. Thus, there was not an opportunity for individuals and their teams to see everyone's scores throughout the trials, which would have provided immediate social comparison and greater levels of pressure. The current study design allowed individuals to leave immediately after the study and forgo experiencing any extensive social comparison. Therefore, it is likely that the non-significant effects of pressure on performance are due to the weak pressure manipulation.

Metacognition and exploration

The third main proposition of the study was that a metacognitive intervention would buffer individuals against the negative effects of pressure on exploration. Examining overall patterns that emerged from the results, it is clear that the metacognitive intervention had a strong positive effect on exploratory behaviors. The pattern of findings regarding the intervention indicates that inducing individuals to think about the task's parameters and their learning allows them to overcome the negative effects of pressure on exploration and explore the task space. That is, when experiencing high levels of pressure, those who received the intervention usually explored the task space more than individuals who did not receive the intervention. Moreover, the effect of the intervention appears to be fairly robust and is consistent even when taking into account individual difference factors and state goal-orientations. These findings are in line with past research demonstrating the positive effects of metacognitive training on transfer and performance on more complex tasks (Bell & Kozlowski, 2008; Elio & Anderson, 1984; Ford et al., 1998). Metacognition involves thinking about the task space and its parameters in order to enhance individuals' understanding and learning. This type of intervention is very similar to reflective thinking interventions (Peden-McAlpine, Tomlinson, Forneris & Meyer, 2005), also referred to as Contextual Learning Interventions (CLT; Forneris & Peden-McAlpine, 2007). These interventions aim to enhance critical thinking, defined as "a process of reflective thinking that goes beyond logical reasoning to evaluate the rationality and justification for actions within context" (Forneris & Peden-McAlpine, 2007, p. 411). Enhanced critical thinking moves individuals' focus beyond achievement and performance to a mindset that is focused on gaining a coherent understanding of the task and the contextual boundary conditions. Metacognition is similar to critical thinking because they both involve higher-level thinking that pushes individuals to focus on learning and understanding of the deeper structures of a given task. Reflective thinking interventions have been shown to have positive effects on performance in field settings. For example, reflective thinking interventions administered over several months have been shown to enhance not only nurses' critical thinking, but the quality of their care giving (Forneris & Peden-McAlpine, 2007; Harrick, 2000). In summary, it appears that interventions that induce individuals to think about a task's parameters and concentrate on learning processes lead to greater exploration, learning of a task space and performance.

Results demonstrated that, consistent with hypotheses, the metacognitive intervention increased performance on the complex task. This finding demonstrates that enhancing exploration for superior problem-solving strategies enhances learning of the task space and performance on complex tasks. Contrary to hypotheses, results demonstrated that the metacognitive intervention did not decrease performance on the simple task. It was hypothesized that the intervention would lead individuals to spend too much time searching for an optimal strategy, leading to lower performance. However, when performing the simple task under pressure, there was little difference in scores between individuals who did and did not receive the intervention. Perhaps individuals who received the intervention learned quickly that exploitation was the superior strategy and, therefore, did not explore the task space extensively. Furthermore, it is possible that once realizing that exploitation was the superior strategy, they were able to exploit more efficiently because they had a deeper understanding of the task's parameters. In contrast, it is possible that individuals in the no intervention condition exploited in a less efficient and more frantic manner (i.e. they moved away from a pool before picking up all of the available resources) because they thought less deeply about the task's parameters. The possibility that individuals in the intervention condition exploited more efficiently in the simple task condition, offsetting the repercussions of exploring when it is wasteful, would explain why there was no difference between the two groups when they differed in the level of exploration.

Individual difference factors

Results indicated that working memory was positively related to exploration. Consistent with predictions and the literature, individuals with high levels of working memory demonstrated greater exploration compared to those with low levels of working memory. However, exactly opposite of predictions, individuals with high, compared to low, levels of working memory benefited more from the metacognitive intervention. One reason for this finding may be that because working memory is so highly related to intelligence (e.g. Colom et al., 2004; Kyllonen & Christal, 1990), individuals high in working memory are more intelligent, allowing them to better utilize the training and understand that the task required exploration to discover an optimal strategy. In other words, the interaction between working memory and metacognition to predict exploration is largely due to intelligence. Supporting this notion, a supplementary analysis not presented in the results demonstrated that working memory was positively related to scores and not just exploratory behaviors, indicating that individuals high in working memory explored when it was necessary. That is, they did not over explore on the simple task.

Some researchers argue that although working memory and *g* are nearly isomorphic constructs, the high correlation between the two constructs is due largely to the storage component of the working memory system and not the processing component (Colom et al., 2005). The measure of working memory used in the current study does not allow for the examination of the unique effects of storage and processing. Therefore, it was not possible to explore the possibility that these findings emerged not because of greater storage capacity (i.e. working memory), but because more intelligent people are better at assessing a task space and recognizing a need to switch between exploratory and exploitative strategies (i.e. processing capacity).

Mediating Mechanisms.

The results from the analyses regarding goal orientations are included in the mediating mechanisms section because the study measured state-level, and not trait-level, goal orientations. The orientations individuals adopted during the task may not reflect stable individual differences. Hence, the predictions and findings with regard to hypotheses 6 a-d must be interpreted with this in mind.

Consistent with predictions and past studies, state mastery orientation was positively related to exploration. This was expected given that mastery orientation is related to learning (Dweck, 1986), which involves searching the task space to understand its complexities and underlying structure. Mastery is also related to adopting more effective learning strategies (Ames & Archer, 1998) that must be acquired by exploring the task space.

Contrary to hypotheses, mastery orientation had minor positive effects on exploration in the high pressure condition, but exerted a strong positive effect when combined with the intervention. These findings are not entirely surprising. The metacognitive intervention induced individuals to reflect on task parameters and explore for optimal strategies, and the mastery state (e.g. orientation to gain a deep understanding of the task) most likely had similar effects. Thus, it is possible that receiving both the intervention and having a high mastery state orientation had an additive effect on exploration, leading to substantially more exploratory behaviors compared to all other groups. In addition, going from low to high mastery in the high pressure condition did not increase exploratory behaviors. It is possible the effects of the pressure manipulation were strong enough to overcome any positive effects high levels of state mastery might exert. It is also interesting to note that individuals low in mastery did not benefit greatly from the intervention. It appears that the lack of orientation to master the task greatly mitigated most of the effects the intervention has on exploration. In summary, it appears that when pressure is high, exploration and performance on complex tasks will be highest when individuals possess of a greater level of mastery toward the task and engage in metacognitive thinking. Having low levels of mastery can offset the beneficial effects that metacognitive interventions may have on task exploration. Similarly, high levels of pressure can negate the inclination to explore in those with high levels of mastery.

Contrary to hypotheses, avoid-performance orientation led to increased exploration. However, in line with predictions, the metacognitive intervention had greater effects on individuals high compared to low in avoid-performance. Specifically, individuals high, versus low, in avoid-performance demonstrated greater exploration when receiving the intervention, but demonstrated less exploration when not receiving the intervention. Moreover, in the low pressure condition, individuals high in avoid-performance explored more than individuals low in avoid-performance. Therefore, it appears that pressure and avoid-performance have additive effects on exploitation, but either low levels of pressure or metacognitive thinking are able to offset the negative effects of high levels of avoid-performance on exploration.

Prove-performance orientation demonstrated an interesting relationship with pressure and exploration. Although individuals across the three pressure conditions did not exhibit different levels of exploration if they were low in prove-performance, exploration differed greatly across conditions for those high in prove-performance. Similar to avoid-performance, when both high levels of pressure and high prove-performance orientation are combined, individuals explored the least. However, if prove-performance orientation during the task was high and was combined with the metacognitive intervention, individuals increased their exploratory behaviors. High pressure combined with high prove-performance orientation most likely had the strongest negative effects on exploration because both pressure and high prove-performance enhance the need to exploit. It is possible that individuals high in prove-performance vigorously apply the strategy that appears optimal; when pressure is high, salient exploitation strategies appear optimal, but when induced to consider the task's parameters through metacognitive thinking, exploration of the task appears optimal.

The current study was unable to examine underlying mechanisms (i.e. mediators) between pressure and exploration because the pressure condition did not predict state goal orientation, or anxiety. As mentioned previously, this is most likely due to the small effects of the pressure manipulation.

Future directions and theoretical implications

Given the findings that individuals must shift between exploration and exploitation strategies depending on the given task's complexity, future studies should examine how individuals are able to recognize a need to shift strategies and individual differences that predict how individuals balance between exploration and exploitation. Research on adaptation as a process explores individuals' ability to monitor one's environment in order to react to changes (Rench, 2009). This area of research may provide insights into the underlying mechanisms that determine how and why individuals shift between exploratory and exploitative behaviors.

Metacognitive interventions appear to have some overlapping features with reflective thinking interventions. Future research should examine the different and overlapping components of the interventions to understand the extent to which metacognitive interventions lead to improved performance through the enhancement of critical thinking. Separating apart aspects that lead to enhanced metacognitive activity (e.g. awareness of self-regulatory processes) versus critical thinking (e.g. considering task parameters and context holistically) will allow for a deeper understanding of the underlying processes between metacognitive training and exploration and performance. Given that performance on the simple task was not harmed by the intervention, despite its strong effects on exploration, researchers should examine if different levels of exploitation efficiency explain why greater metacognitive thinking does not harm performance on simple tasks. Furthermore, future research should examine different types of exploitative and explorative strategies individuals may adopt and how metacognition impacts the selection, transition and balance between different strategic actions. For example, Reinmoeller (2006) used metacognitive skills to explain the underlying process of how entrepreneurs integrate information in order to strike a proper balance between exploration and exploitation.

Working memory demonstrated a positive impact on exploration. The current study was not able to examine neither the unique effects of working memory over intelligence nor the unique effects of the components of working memory. Therefore, future research should examine whether working memory is related to greater exploration and performance due to storage, processing or both, indicating whether its beneficial effects are due to intelligence and processing capacity and/or to working memory and storage capacity.

A fruitful avenue for future research is to examine individual difference factors that may mitigate the negative effects of pressure on exploration and performance on complex tasks. For example, trait level curiosity may influence individuals' proclivity to explore a given task. Trait curiosity is a desire for new information and manifests itself through inquisitive and exploratory behaviors (Berlyne, 1960, 1966; Litman, 2005). It involves the capability to learn to adapt to novel environments and the ability to explore and experiment to gain an understanding of a given situation (Ashforth, Sluss & Harrison, 2007). Some researchers have argued that high levels of trait curiosity help individuals manage changing environments (Weick, 1993), which can often be full of pressure and stress. Therefore, given that curiosity enhances individuals' inclination to explore and manage difficult environments, future research should examine the extent to which it prevents pressure from inhibiting exploration and inducing exploitation. Research has shown that trait curiosity is related to problem exploration in children (Inagaki, 1978) and workplace learning and job performance in adults (Reio & Wiswell, 2000). Some researchers have proposed that different types of curiosity differentially predict various exploratory behaviors. For example, Berlyne (1966) proposed two dimensions of trait curiosity; specific curiosity is associated with narrow and direct forms of exploration, whereas diversive curiosity is associated with broader and indirect forms of exploration. Preliminary research has provided some evidence for the two-dimension model of curiosity. In a sample of newly hired telemarketers, specific curiosity was related to information seeking behaviors and diversive curiosity was related to positively reframing tasks to view them more as a challenge than a problem (Harrison et al., 2007). Future research should examine how different types of trait curiosity interact with the task context to predict different types of exploratory behaviors and performance.

Personality traits that predict learning styles may play an important role in predicting what level of exploratory versus exploitative behaviors individuals adopt and how pressure may influence this balance. For instance, as individuals are more inclined to engage in deep learning, they are more likely to search a task space for various strategies in order to discover the optimal strategies and master the challenge. Individuals who are more inclined to adopt surface learning approaches are more likely to adopt simple and salient strategies, and exploit them. Researchers have begun to demonstrate a strong link between the Big Five personality traits and learning styles. Zhang (2003) found that Conscientiousness and Openness are positively related to deep learning strategies and Openness is negatively related to surface learning strategies. Zhang also found that Neuroticism is negatively related to deep learning strategies and positively related to surface learning strategies. Other researchers have similarly demonstrated that Conscientiousness, Openness, Agreeableness and Extraversion are all positively related to reflective learning styles (e.g. synthesis analysis, elaborative processing), while Neuroticism is negatively related to reflective learning styles (Komarraju, Karau, Schmeck & Avdic, 2011). Furthermore, some research has linked the Big Five traits directly to various types of exploratory behaviors, such as search efficacy and information seeking (Reed, Bruch & Haase, 2004). Future research should explore how the Big Five traits predispose individuals to adopt different learning strategies and how traits related to exploration and deep learning buffer individuals against the effects of pressure. Other individual difference factors that may affect individuals' predisposition towards exploratory behaviors and their ability to explore in the face of pressure are tenure, expertise, self-confidence, self-efficacy, competency and proactive personality.

Practical Implications

The metacognitive intervention, despite being short in duration, had strong effects on exploration and performance, and these effects were fairly robust. This has important implications for practitioners. Metacognitive thinking skills should be included in training programs for complex and stressful positions, given that past studies and current results demonstrate that metacognition has a substantial impact on learning, exploration and performance. More important, the current study provides evidence to support the notion that enhancing metacognitive skills helps individuals perform complex tasks under pressure. Given the increasing pressure the global market places on organizations and their employees (Hagel, Brown & Davison, 2008), an intervention that helps individuals perform to their full potential under difficult and changing environments will help individuals and their organizations excel.

The positive effects of working memory on exploration and performance have important implications for organizations. If the effects stem partly from working memory, then there is a potential for organizations to enhance working memory through training interventions (Verhaeghen, Cerella & Basak, 2004). However, if *g* is largely responsible for the working memory and performance and exploration relationship, organizations will either have to train other important employee characteristics or select for intelligence, as *g* is less malleable. Despite the effects of working memory and intelligence, I do not want to overplay their importance. The results indicate that the intervention had a much greater impact on exploration than did working memory. Therefore, organizations ought to focus more on developing metacognitive skills before considering training or selecting for working memory. Moreover, high levels of working memory and intelligence may matter less for low complexity jobs that do not require exploration.

The findings concerning state goal orientations have several implications for practitioners. First, the findings concerning mastery orientation indicate that in order to enhance performance for complex jobs under pressure, practitioners utilizing metacognitive training strategies must ensure that individuals adopt a mastery orientation toward their job. Inducing employees to adopt a mastery orientation will ensure that they reap the maximal benefits from the metacognitive training. Moreover, practitioners must also consider employee performance orientations; if they are low, interventions may have null or negative effects on exploration, but if they are high, interventions may exert positive effects on exploration. Practitioners must keep this in mind when designing and implementing selection strategies as well; these findings will most likely emerge with trait goal orientations. Therefore, when selecting employees for a complex and stressful position, selecting for certain types of trait goal orientations is important, especially when considering the type of training the employees will receive.

Limitations

The current study had several limitations. First, subjects were recruited from a subject pool to complete a lab task. Therefore, the generalizability is weakened due to the sample and the lab context. To enhance generalizability, future studies should replicate these findings using actual work tasks and representative field samples. Despite this limitation, many areas of research first demonstrate basic psychological phenomena in lab settings and aim to replicate the findings in field settings once a thorough understanding of the phenomena is acquired.

Second, data was collected from one source, making the data susceptible to common method bias. However, the performance data was collected behaviorally and individual difference factors and potential mediators were collected with self-report measures. Separating measures methodologically can help reduce the threat of common method bias (Podsakoff, MacKenzie, Lee & Podsakoff, 2003). Therefore, it is unlikely that common method variance is a likely alternative explanation for the current findings.

Third, only one type of pressure (i.e. social comparison) was used and it did not exert strong effects on individuals perceived level of pressure or anxiety. Despite the non-significant differences between the low pressure and high pressure groups, and the intervention and high pressure groups, the pressure manipulations still exerted small amounts of pressure. The majority of past studies directly examining pressure effects on performance have used multiple forms of pressure (e.g. Beilock's studies). Therefore, future studies must examine different types of pressure separately in order to understand unique effects of each source of pressure.

Fourth, the current study was not able to thoroughly examine strategy search and adoption in order to validate the metacognitive intervention. Although individuals in the high pressure with the intervention group enhanced their scores sooner than the high pressure group, neither group significantly changed their exploration across trials. Therefore, it is unclear whether individuals who received the metacognition demonstrated greater performance because they exhibited greater metacognitive activity, learned the task quicker and adopted superior strategies as they progressed. It is possible the intervention had positive effects because it enhanced focus and motivation or other beneficial attitudinal and motivational factors.

Last, the current study examined the effects of pressure during very short performance episodes. The dynamic interaction between performance and pressure over time was not examined. It is likely that the dynamic process plays an important role when working on challenging projects over long periods of time. Thus, examining this process over longer durations is an important future step.

Conclusion

The current study demonstrates that individuals need to use varying levels of both exploratory and exploitative behaviors depending on the complexity of their task. Success at one's career will depend on managing that balance and future research should aim to understand how individuals can enhance the quality of this equilibrium. Metacognitive thinking enables individuals to think thoroughly and strategically under pressure, allowing them to succeed in difficult environments. In summary, to perform at one's best in today's pressure filled and competitive business environment, individuals must learn not only to shift between exploration and exploitation, but they must ensure pressure does not disrupt this important balance.

APPENDICES

APPENDIX A

Tables

Table 1. *Means, Standard Deviations and Intercorrelations Among Study Variables.*

Variable	*N*	*Mn*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Mastery	157	3.51	.67										
2. Perf avoid	160	2.34	.62	.18*									
3. Perf prove	160	3.10	.85	.31*	.43*								
4. Anxiety	146	2.41	.61	-.18*	.33*	.28*							
5. WM	173	30.22	5.80	.13	.04	.06	-.14						
6. Exploration	176	0	.62	.16*	.03	.05	-.12	.08					
7. Score	176	639.45	282.97	.14	-.04	.09	-.15	.14	.61*				
8. Complex	176	.55	.50	.21*	-.03	.07	.01	-.04	.41*	.56*			
9. Low Press	176	.28	.45	-.02	-.13	-.12	-.05	.03	.07	-.03	-.04		
10. Hi Press + Intervention	176	.34	.48	-.02	.13	.06	.08	-.11	.14	.07	.022	-.45	
11. Gender	155	.38	.49	.02	-.06	.07	-.09	.01	.18*	.13	.05	-.02	.03

NOTE: * = p < .05. Exploration is standardized. WM = Working Memory; Low Press = Low Pressure group; Hi Press + Intervention = High Pressure with the Metacognitive Intervention group.

Table 2. *Interaction between Exploration and Complexity predicting Performance.*

		b	*SE*	Beta
Step 1				
	Constant	611.37	28.11	
	Gender	73.23	45.56	
Step 2				
	Constant	517.09	30.15	
	Gender	20.49	34.99	.04
	Exploration	190.53	31.06	.41*
	Complexity	213.63	36.58	.38*
Step 3				
	Constant	453.70	54.17	
	Gender	21.99	34.89	.04
	Exploration	-25.58	156.72	-.06
	Complexity	274.97	56.84	.50*
	Exploration X Complexity	224.41	159.53	.44

Note: $^{*}p < .05$. Complexity was dummy coded where 0 represented low complexity and 1 represented high complexity.

Table 3. *Interaction between Complexity and Pressure condition predicting Performance.*

		b	*SE*	Beta
Step 1				
	Constant	611.37	28.11	
	Gender	73.23	45.56	.13
Step 2				
	Constant	436.14	39.01	
	Gender	55.72	38.28	.10
	Complexity	295.27	37.60	.53*
	Low Pressure	-14.43	46.07	-.02
	High Pressure + Intervention	60.39	44.01	.10
Step 3				
	Constant	451.31	46.54	
	Gender	56.53	38.61	.10
	Complexity	237.62	61.08	.48*
	Low Pressure	-10.00	67.23	-.02
	High Pressure + Intervention	3.0	68.99	.01
	Complexity X Low Pressure	95.75	89.87	.14
	Complexity X High Pressure + Intervention	-12.13	93.05	-.02

Note: $^{*}p < .05$. Complexity was dummy coded where 0 represented low complexity and 1 represented high complexity. Low pressure was dummy coded where 0 represented high pressure and 1 represented low pressure. High pressure + intervention was dummy coded where 0 represented high pressure and 1 represented high pressure + intervention.

Table 4. *Interaction between Mastery and Pressure Condition predicting Exploration.*

		b	*SE*	Beta
Step 1				
	Constant	-.15	.05	
	Gender	.28	.09	.25*
Step 2				
	Constant	-.75	.23	
	Gender	.26	.08	.24*
	Mastery	.14	.06	.16*
	Low Pressure	.04	.10	.03
	High Pressure + Intervention	.34	.10	.30*
Step 3				
	Constant	-.36	.41	
	Gender	.28	.08	.25*
	Mastery	.03	.11	.03
	Low Pressure	.32	.57	.27
	High Pressure + Intervention	-.81	.53	-.72
	Mastery X Low Pressure	.33	.15	1.05*
	Mastery X High Pressure + Intervention	-.08	.16	-.25

Note: $^{*}p < .05$. Low pressure was dummy coded where 0 represented high pressure and 1 represented low pressure. High pressure + intervention was dummy coded where 0 represented high pressure and 1 represented high pressure + intervention.

Table 5. *Interaction between Avoid-Performance and Pressure Condition predicting Exploration.*

		b	*SE*	Beta
Step 1				
	Constant	-.15	.05	
	Gender	.27	.09	.25*
Step 2				
	Constant	-.34	.18	
	Gender	.27	.09	.24*
	Avoid-Perf	.03	.07	.03
	Low Pressure	.06	.11	.05
	High + Int vs High	.35	.10	.31*
Step 3				
	Constant	-.29	.17	
	Gender	.28	.08	.25*
	Avoid-Perf	.00	.07	.00
	Low Pressure	.23	.42	.19
	High + Int vs High	-.89	.35	-.78*
	Avoid-Perf X Low Pressure	.35	.10	1.13*
	Avoid-Perf X High + Int vs High	-.05	.12	-.14

Note: $^{*}p < .05$. Low pressure was dummy coded where 0 represented high pressure and 1 represented low pressure. High pressure + intervention was dummy coded where 0 represented high pressure and 1 represented high pressure + intervention.

Table 6. *Interaction between Working Memory and Pressure Condition predicting Exploration.*

		b	*SE*	Beta
Step 1				
	Constant	-.12	.06	
	Gender	.23	.10	.19
Step 2				
	Constant	-.64	.25	
	Gender	.22	.10	.18*
	WM	.01	.01	.12
	Low Pressure	.14	.12	.11
	High Pressure + Intervention	.36	.11	.29*
Step 3				
	Constant	-.58	.42	
	Gender	.22	.10	.18*
	WM	.01	.01	.10
	Low Pressure	.00	.72	.00
	High Pressure + Intervention	.29	.54	.23
	WM X Low Pressure	.01	.02	.11
	WM X High Pressure + Intervention	.00	.02	.06

Note: $^{*}p < .05$. Low pressure was dummy coded where 0 represented high pressure and 1 represented low pressure. High pressure + intervention was dummy coded where 0 represented high pressure and 1 represented high pressure + intervention.

Table 7. *Interaction between Prove-performance and Pressure Condition predicting Exploration*.

		b	*SE*	Beta
Step 1				
	Constant	-.11	.06	
	Gender	.22	.10	.18*
Step 2				
	Constant	-.27	.19	
	Gender	.22	.10	.18*
	Prove-perf	.00	.06	.01
	Low Pressure	.13	.12	.10
	High Pressure + Intervention	.34	.11	.27*
Step 3				
	Constant	.06	.30	
	Gender	.21	.10	.17*
	Prove-perf	-.10	.09	-.14
	Low Pressure	-.19	.42	-.14
	High Pressure + Intervention	-.43	.45	-.34
	Prove-perf X Low Pressure	.24	.14	.64
	Prove-perf X High Pressure + Intervention	.10	.13	.24

Note: $^{*}p < .05$. Low pressure was dummy coded where 0 represented high pressure and 1 represented low pressure. High pressure + intervention was dummy coded where 0 represented high pressure and 1 represented high pressure + intervention.

Table 8. *Means and Standard Deviations of scores for the High Pressure and High Pressure with Metacognitive Intervention Groups.*

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
High Pressure	520 (297)	558 (305)	634 (362)	650 (356)	748 (401)
High Pressure + Metacognitive Intervention	551 (318)	637 (367)	642 (352)	758 (402)	766 (404)

Note: $*p < .05$.

Table 9. *Mean differences in scores between trials for the High Pressure and High Pressure with Metacognitive Intervention Groups*.

	Trial 1 to 2	Trial 2 to 3	Trial 3 to 4	Trial 4 to 5
High Pressure	38	75	17	98*
High Pressure + Metacognitive Intervention	86*	4	116*	7

Note: *$p < .05$. Cells that are starred for a given trial indicate that the means differ from each other.

Table 10. *Means and Standard Deviations of Exploration for the High Pressure and High Pressure with Metacognitive Intervention Groups.*

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
High Pressure	-.23 (.59)*	-.19 (.64)	-.15 (.97)*	-.24 (.61)*	-.19 (.72)*
High Pressure + Metacognitive Intervention	.14 (.96)*	.08 (.97)	.20 (1.05)*	.16 (1.10)*	.22 (1.23)*

Note: *$p < .05$.

Table 11. *Mean differences in exploration between trials for the High Pressure and High Pressure with Metacognitive Intervention Groups.*

	Trial 1 to 2	Trial 2 to 3	Trial 3 to 4	Trial 4 to 5
High Pressure	.05	.04	-.09	.05
High Pressure + Metacognitive Intervention	-.06	.12	-.04	.06

Note: **p* < .05. Cells that are starred for a given trial indicate that the means differ from each other.

APPENDIX B

Figures

Figure 1. *Model of the Effects of Pressure on Performance.*

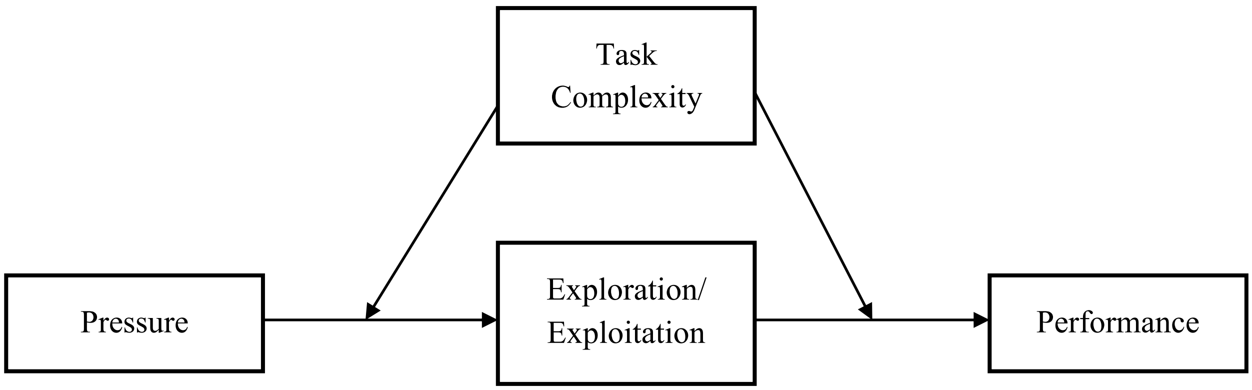


Figure 2. *Interaction between exploration and complexity predicting performance.*

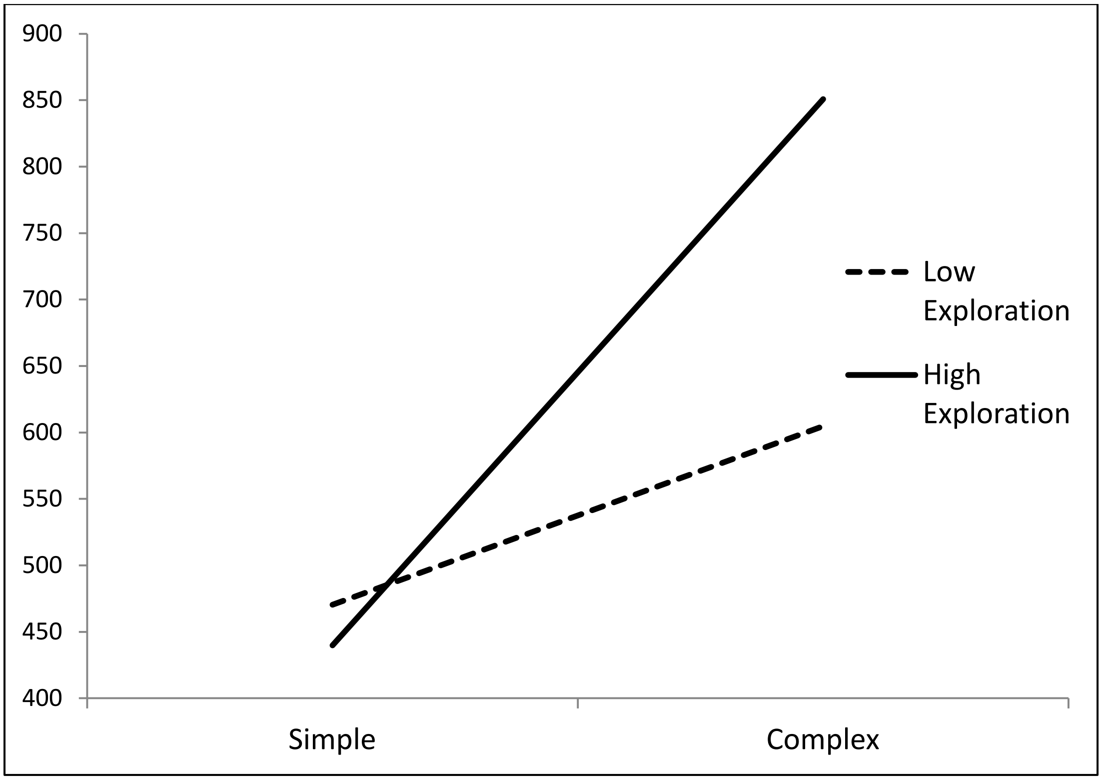


Figure 3. *Interaction between Complexity and Pressure Condition predicting Performance*.

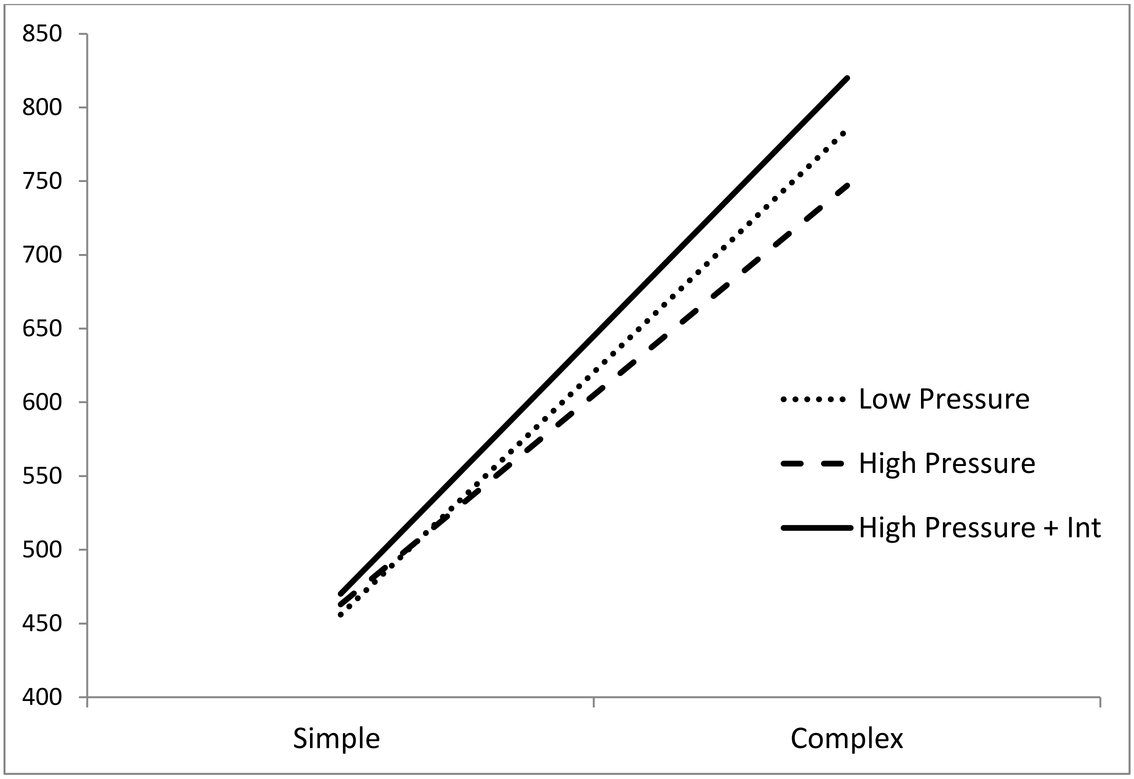


Figure 4. *Interaction between State Mastery Orientation and Pressure predicting Exploration.*

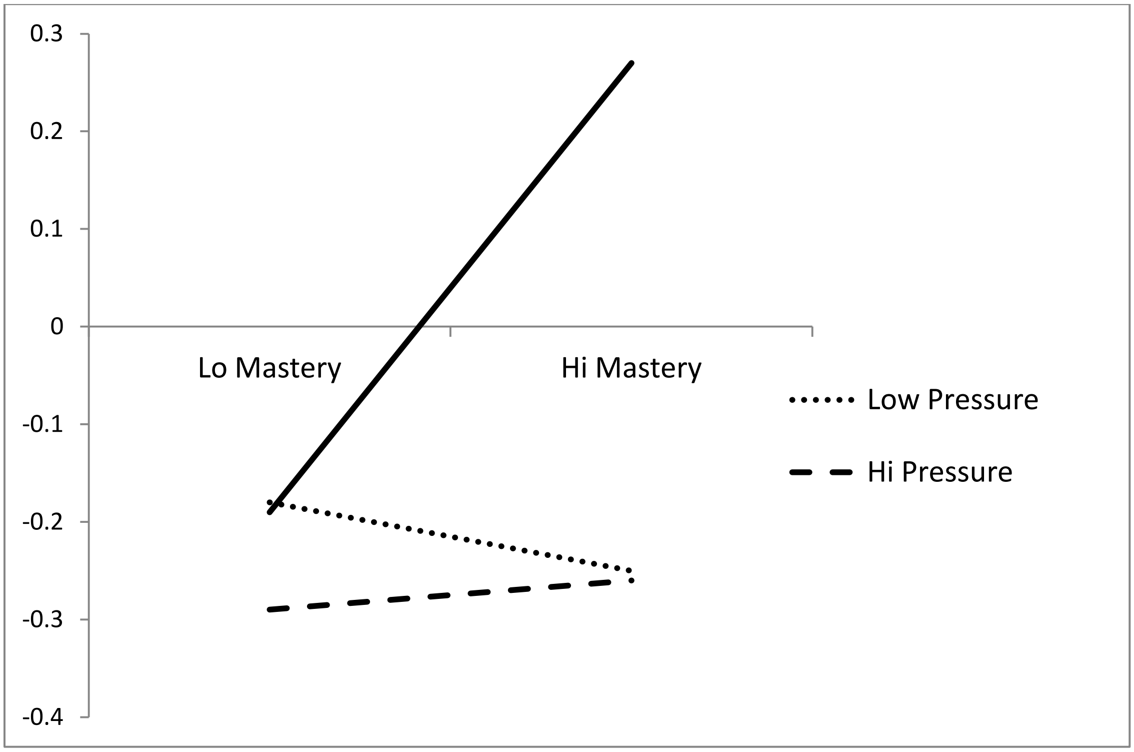


Figure 5. *Interaction between Avoid-performance and Pressure Condition predicting Exploration.*

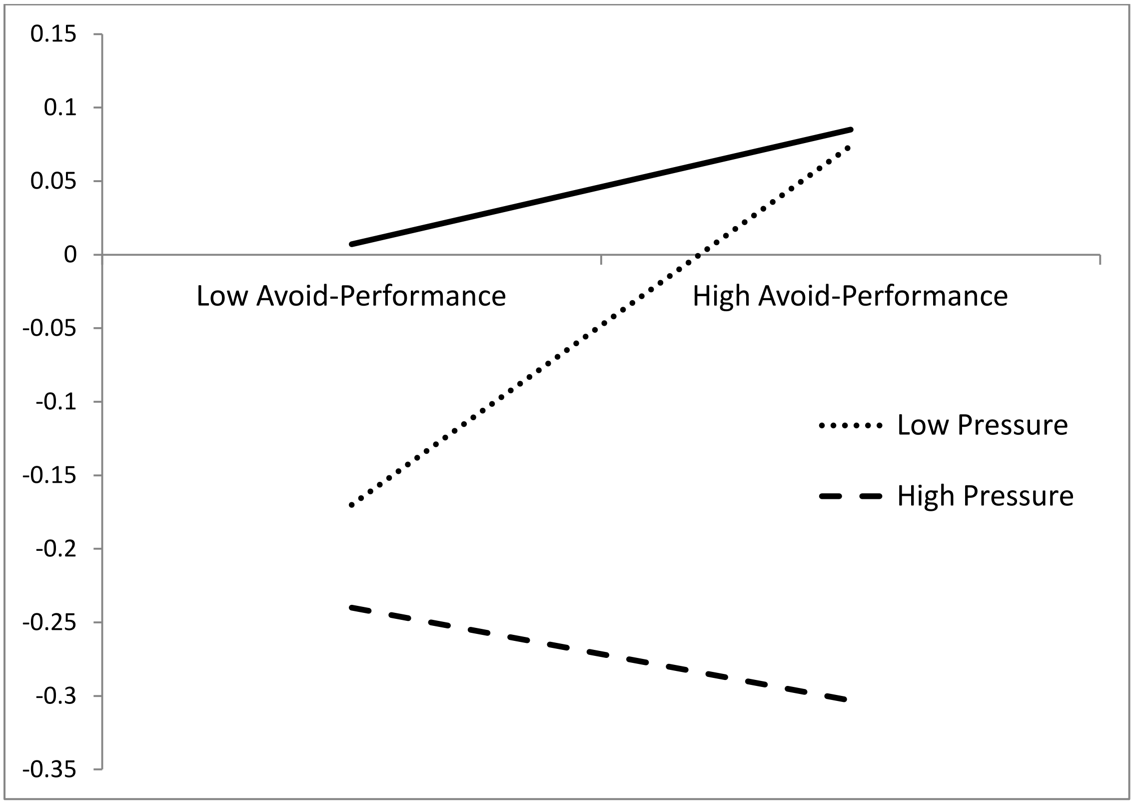


Figure 6. *Interaction between Working Memory and Pressure Condition predicting Exploration.*

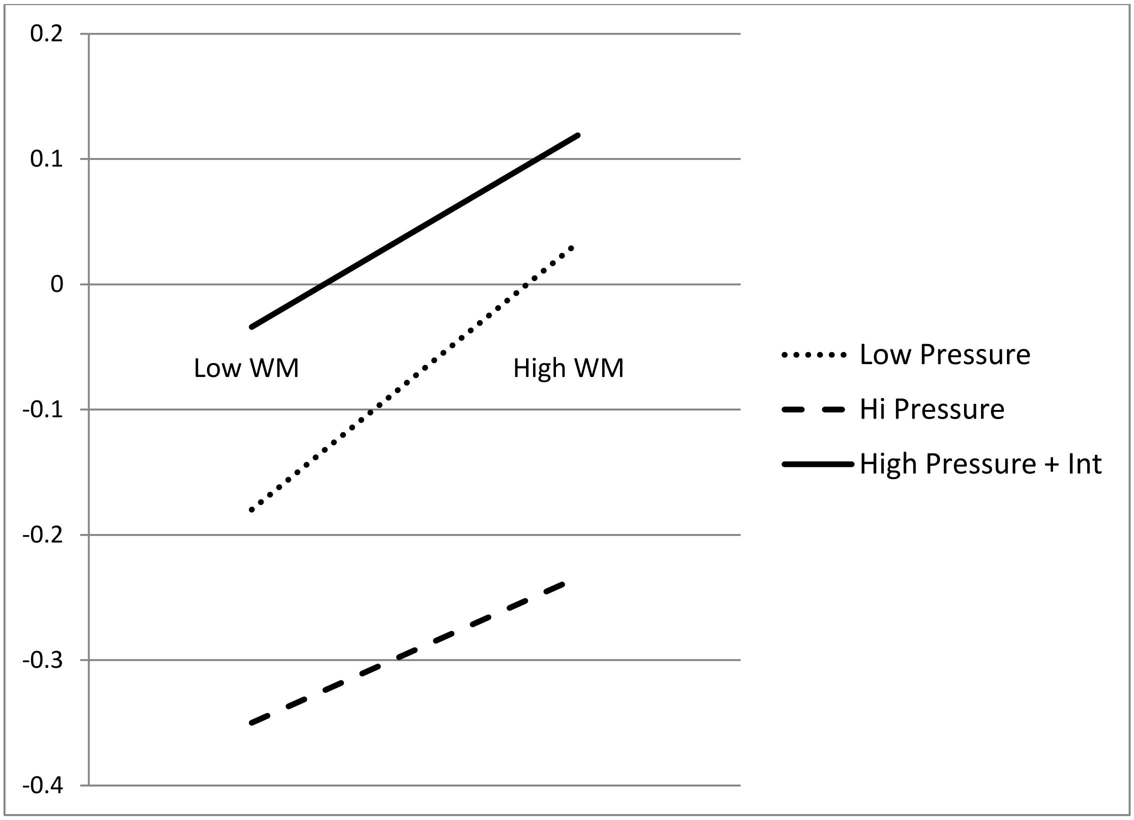
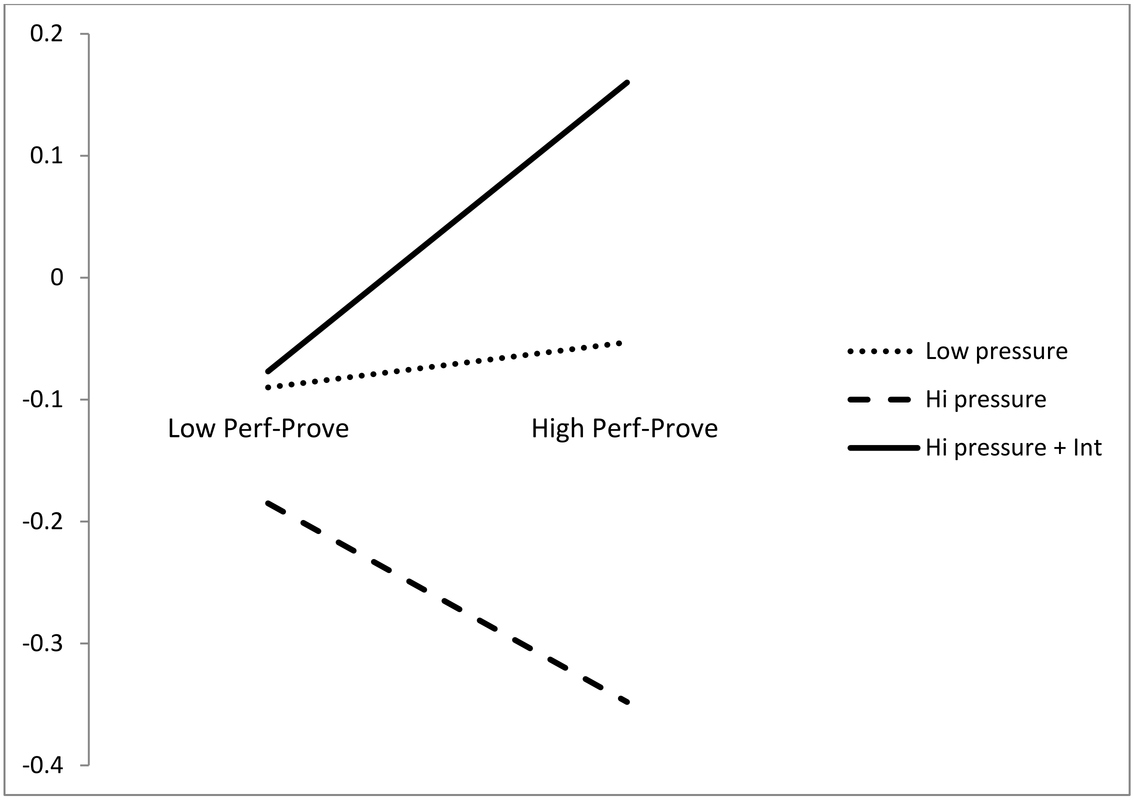


Figure 7. *Interaction between Prove-Performance and Pressure to predict Exploration.*



Appendix C

Intervention and Measures

Intervention Script

Metacognition is the knowledge and control you have over your own thoughts. It includes the awareness you have of how you learn and what you know. When you are using metacognition, you are thinking about the processes of your thoughts, what you know, and what you need to do to be a better learner.

Metacognition has been shown to increase awareness, comprehension, self-confidence, and the use of effective strategies in tasks like the one you are currently participating in. Science has shown that it is in your best interest to utilize the metacognitive techniques you have been taught not just during this task (which is important) but really for anything else you do in life.

Ask yourself questions about what you know.

What are the parameters of the game?

How is the move and collection delay related to how far I can travel and how many resources I can collect?

Ask yourself about how you could better strategize and do things better.

What do I need to do to collect the most valuable resources?

Think about your planning efforts and how you could improve them.

What is hurting my score the most? How can I change that?

How could I be more systematic about improving my performance?

REMEMBER: Learning to ask these questions will help your performance in the game after when training is complete and you are faced with new challenges.

Another aspect of engaging in metacognitive activity is exploring a problem space. This involves engaging in an active search for effective problem-solving strategies. Science has demonstrated that exploring a task and developing your own understanding of it is an effective method for learning. Therefore, be sure to explore the task to understand what is occurring, and to discover the best strategy to deal with the situation. Also, experiment with different strategies and methods as you explore the task and learn important task skills. Remember, your task is to achieve the highest total score. Ask yourself if you have thoroughly explored the task and experimented with different strategies. Even if you feel rushed, hurried or pressured, remember to ask yourself if you have properly searched for and found an effective strategy that will produce your highest potential performance.

Metacognitive training questions (answered after each trial). Please briefly respond to the following questions

1. What are the parameters of the game?
2. How is the move and collection delay related to how far I can travel and how many resources I can collect?
3. What do I need to do to collect the most valuable resources?
4. What is hurting my score the most? How can I change that?
5. How could I be more systematic about improving my performance?
6. Have I explored the task and experimented with different strategies?

Goal Orientation Scale

Factor 1: Learning Goal Orientation

1. I am willing to select a challenges that I can learn a lot from.
2. I often look for opportunities to develop new skills and knowledge.
3. I enjoy challenging and difficult activities where I'll learn new skills.
4. For me, development of my abilities is important enough to take risks.

Factor II: Prove-Performance Goal Orientation

5. I prefer to do things that require a high level of ability and talent.
6. I'm concerned with showing that I can perform better than my peers.
7. I try to figure out what it takes to prove my ability to others.
8. I enjoy it when others are aware of how well I am doing.
9. I prefer to in things where I can prove my ability to others.

Factor III: Avoid-Performance Goal Orientation

10. I would avoid taking on a new task if there was a chance that I would appear rather incompetent to others.
11. Avoiding a show of low ability is more important to me than learning a new skill.
12. I'm concerned about taking on a task if my performance would reveal that I had low ability.
13. I prefer to avoid situations where I might perform poorly.

OSPAN

This task is called **OPERATION SPAN.** It is a test of working memory.

On each slide, you will see a simple math problem, which will be followed by an answer that is either correct or incorrect and by a word displayed in red. There are two parts to the task:
First, read the equation aloud, and say **YES** if the answer is correct or **NO** if it is incorrect. Then silently read and try to remember the word in red, because a prompt (???) will appear after some number of slides and your job will be to write down the words in the order in which they appeared.

An example:

On the first screen, suppose you saw the following equation and then the word **DOG**.

IS (3 x 1) + 1 = 5 ?

You would read the equation aloud and say **NO** because the answer is 4 instead of 5. That is, you would say: “Is three times one plus one equal five…NO.” Then you would silently read the word **DOG** and remember it for later.

Next, suppose you saw the following equation and then the word **SNOW**.

IS (4 ÷ 1) + 2 = 6 ?

You would read the equation aloud (as just explained) and say **YES** because **6** is the correct answer. Then you would silently read the word **SNOW** and remember it along with **DOG**.

Finally, assume that ??? appeared after two equation-word pairs. At this point, but not before, you would write **DOG** in the first blank on your response sheet and **SNOW** in the second blank.

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