

# THE EFFECTS OF FEEDBACK ON WORKING MEMORY CAPACITY

by

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(Under the Direction of Adam Goodie)

## ABSTRACT

Working memory (WM) is an essential component of the cognitive system, which is limited in capacity and requires attentional control to actively maintain information in the presence of internal and external distraction. An individual's working memory capacity (WMC), measured via complex WM span tasks, indicates one's ability to maintain task relevant information accessible in a highly active state, particularly when interference is present (Unsworth, Schrock, & Engle, 2004). While WMC has traditionally been considered to be a trait variable (Conway et al., 2005), recent research suggests state variable characteristics (i.e., temporary variations) associated with WMC. Such variations have been found in conditions that consume WM, such as anxiety, pressure, and intrusive thoughts (Beilock & Carr, 2001). The present study seeks to examine these phenomena via providing false feedback as a manipulation to examine temporary changes in one's WMC. The participants performed one working memory task, followed by a manipulation of either negative or positive feedback, then completed a second highly correlated working memory task. The results revealed that the manipulation affected participants' performance on a subsequent second WM task. These results confirm that it is possible to temporarily change the amount of WMC available.

Participants in the positive feedback condition revealed significant improvement on the second task, suggesting their WM was freed up to maintain more focus on the task. Participants in the negative feedback condition performed poorer on the second task, suggesting their WMC was reduced due to rumination about their prior performance.

INDEX WORDS: Working Memory, Feedback

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## DEDICATION

To my children, Justus, Ashlee, and Jacob, anything is possible and it is never too late to accomplish the great things you desire in life.

## ACKNOWLEDGEMENTS

I am proud to be the first in my family to achieve a bachelor's degree and now a master's degree. That being said, it would not have been possible without the support of my family, friends, and mentors who pushed me to my limits.

I was fortunate enough to have several mentors as an undergraduate student. I would like to thank Shawn Charlton for introducing me to the world of research. Additionally, I would like to thank Paul Nail for his persistence and never accepting less than my best. I would like to thank Ken Sobel for the hours upon hours of his time, brainstorming ideas and passing on his passion for Cognitive Psychology.

As a graduate student, I had the privilege of working with one of the great researchers who contributes so much to the field of working memory. Even if it was only for a year, that year taught me so much about researching working memory. Actually, it was by reading his publications as an undergraduate, which ignited the passion to study working memory. I also had the brief privilege of working with one of the greatest mentors, Richard Marsh. Unfortunately, many suffered from his untimely death. However, every minute spent with Rich will always remain in my memory.

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## CHAPTER 1

### INTRODUCTION

Working memory can be defined as a mental system responsible for the active maintenance, manipulation, and retrieval of task relevant information, including the ability to maintain a high level of controlled attention. It is important to note that working memory (WM) is not essential in situations where distractions are not present (Unsworth & Engle, 2007b). Cognitive psychologists commonly distinguish between automatic mental processes not requiring high levels of WM and those that require conscious effort, where WM is necessary.

Fundamentally, WM is critical in higher order cognitive tasks, in addition to tasks where distractions or interference is present. Working memory is an essential cognitive construct that individuals rely on constantly. For example, forgetting to stop by the store while thinking of other things on the way home. The reason for this is driving a familiar route is an automatic process requiring little conscious control. Whereas, the addition of stopping by the store may not be a typical daily routine, therefore it requires controlled attention to countermand a habitual tendency (Unsworth et al., 2004).

The notion of WM has a long history in psychology; however, Baddeley and Hitch (1974) developed the first model of WM, suggested two individual stores: the phonological loop, used for brief storage of verbal information, and the visual-spatial sketchpad for the brief storage of images. More critically, a third component was argued to be the central executive that was presumed to allocate limited attentional resources (Baddeley & Hitch, 1974). Four decades later scientists are still attempting to understand the central executive, since it may be the least

understood concept of the WM system (Unsworth et al., 2004; Unsworth & Engle, 2007c). Cowan (1998) introduced a model of WMC contributing to the rapid advancement in the research of WMC. The model emphasized the role of attention in the WM process; this model tends to be the current model used by many cognitive psychologists (Conway & Engle, 1994; Engle, Conway, Tuholski, & Shisler, 1995; Engle, Kane, & Tuholski, 1999; Unsworth et al., 2004). In fact, Cowan's (1988) model of the WM system pioneered the direction of research from the structures of WM to the functions (Cowan, 1988; Engle, 2010; Heitz & Engle, 2007).

### *Working Memory Capacity*

Daneman and Carpenter (1980) developed the first valid measurement of WMC using memory span tasks. Their complex memory span task required participants to read a sentence while attempting to remember a short list of words, thus providing a secondary load on WM. The span task revealed a great deal of validity, because it has proven to predict other real-life higher cognitive processes. For example, the results were highly correlated ( $r$ s reaching .90) in areas of the Scholastic Aptitude Test (Kane, Bleckley, Conway, & Engle, 2001). Such compelling correlations led researchers to develop additional complex memory span tasks, such as the Operation Span Task (OSPAN; Turner & Engle, 1989).

Aside from standardized intelligence tests, span tasks are among the most widely used instruments to measure cognitive abilities (Conway et al., 2005). Further, span tasks have proven to be reliable and valid predictors of additional higher order cognitive processes, such as problem solving (Engle, 2002), reasoning (Conway, Cowan, Bunting, Therriault & Minkoff, 2002) and fluid intelligence (Conway, 2003; Conway, Kane, & Engle, 2003; Unsworth & Engle

2007c), in addition to lower-level attentional tasks (Heitz & Engle, 2007; Heitz, Schrock, Payne & Engle, 2007).

### *Executive Attention Theory*

Engle and Kane (2004) proposed the executive attention theory of WMC. Following Cowan's model of WMC, the theory stresses the importance of controlled attention, or executive attention. This further suggests that executive attention is the mechanism responsible for individual differences in WMC. The authors explained that the individual differences in WMC were a result of cognitive processes, which demand high levels of executive attention. Growing research vis-à-vis individual differences in working memory capacity (WMC) has produced abundant literature relevant to understanding the functions of the working memory system (Poole & Kane, 2009).

Individual differences in WMC most often manifest in situations when irrelevant distractions or interferences make goal maintenance difficult (Conway & Engle, 1994; Engle et al., 1995; Engle, Kane, & Tuholski, 1999; Unsworth & Engle, 2007a), or when controlled attention is necessary to maintain goals that are in opposition to automatic processes (Engle & Kane, 2004).

An abundance of literature examining individual differences in WMC has revealed that individuals with high WMC (high spans) have a repertoire of strategies useful in high-level cognitive task at their disposal than do those individuals with low WMC (low spans). These cognitive memory strategies include mnemonics, chunking of information, and rehearsal (Conway & Engle, 1994; Cowan, 1998; Conway et al., 2002; Kane, Conway, Hambrick, & Engle, 2007; Unsworth & Engle, 2005; Unsworth & Engle, 2007a; 2007b).

### *Attention and Working Memory Capacity*

According to the executive attention theory, WMC represents differences in executive attention. Evidence, in support of this notion shows that individual differences in WMC reliably predict performances on low-level attention tasks. Significantly, both high- and low-level cognitive processes rely on WMC (Engle & Kane, 2004). Both constructs are of primary interest concerning the present study. The attentional demands, or the ability to maintain focused attention, to the task is essential to the study, while higher order cognition is required to complete the tasks. Three attentional tasks are described to provide insight of the attention aspect of WM most relevant to the present study. The tasks include the Stroop task (Stroop, 1935), the dichotic listening task (Cherry, 1953) and the anti-saccade task (Unsworth et al., 2004).

The Stroop task (1935) has a long history in cognitive psychology used to examine the ability to block or inhibit competing stimulus, often counter to one's natural responses. In a study by Kane and Engle (2003) the participants were confronted with given names of colors that were presented either in a font of either a different color (e.g., the word "red" was printed in a green colored font) or of the same color (e.g., "red" presented in a red colored font). Participants were then instructed to name the color in which the word was presented. In some instances the word and the color of the ink in which it was printed were congruent, and in other instances they were incongruent. In the trials that have more congruent associations, high span participants performed significantly better than low span participants. However, in the non-congruent trials, both hi and low spans performed equally well. Kane and Engle (2003) argued that low spans exhibited greater goal-neglect (i.e., failure to maintain attention on goal relevant information) when the task demanded a higher level of goal maintenance.

The dichotic listening task, first developed by Cherry (1953), commonly known for the “cocktail party” effect, is another task that requires participants to refrain from habitual responses. Participants wore headphones and were asked to shadow words from a relevant channel while ignoring information from the irrelevant, to be ignored channel. The irrelevant channel would speak the participant’s name among a series of irrelevant words. In a recent study Conway, Cowan, and Bunting (2001) tested both high and low spans, determined by the participant’s OSPAN scores. The results of their study revealed that only 20% of high spans detected their name when it was presented as opposed to 65% of low spans. These findings indicate that low spans have more difficulty resisting the lure of a powerful, orienting cue than do high spans.

The anti-saccade task instructs participants to look away from a flashing cue, considered a prosaccade response. The other response is saccade, where participants are instructed to look toward the flashing cue. Since the cue captures attention, the anti-saccade condition requires the inhibition of a prepotent response and a controlled saccade in the opposite direction. A recent study that examined WMC and anti-saccade revealed there were no significant differences in the performance of low span and high span participants in the prosaccade task (Unsworth et al., 2004). However, in the anti-saccade task low spans made significantly more errors than high spans. Unsworth and colleagues suggested the reason to be a deficiency in low span individuals to maintain sustained attention, when controlled attention was required, as opposed to tasks that required only automatic responses (Unsworth et al., 2004).

### *Characteristics of Working Memory Capacity*

Working memory capacity has historically been considered to be a trait variable (Ackerman, Beier, & Boyle, 2005; Engle & Kane, 2004). According to Engle & Kane (2004) WMC is an abiding trait of the individual, suggesting that it is consistent and enduring, tending not to fluctuate across the person's life span (Conway et al., 2005). Further supporting this notion, Klein and Fiss (1999) demonstrated that individuals were consistent in performance on WM span tasks based on several administrations over an extended period of time.

### *Performance and Anxiety*

The causes and effects of anxiety have long intrigued social psychologists. Relevant to the current study, recent literature has investigated the cognitive mechanisms involved in the reductions in performance related to anxiety. Researchers have suggested the cause of decreased performance to be related to WMC (Ashcraft & Kirk, 2001; Beilock & Carr, 2005; Engle, 2010; Ilkowska & Engle, 2010; Kane et al., 2007; Schmader, 2010; Unsworth, Heitz, Schrock & Engle, 2005). In fact, a number of studies report that temporary reductions in WMC are the cause for decreased performance (Eysenck & Calvo, 1992; Schmader & Johns, 2003).

The present study focused on three of the situations in the current literature, each of which has attributed WMC as the cognitive mechanism involved in performance decrements resulting from situations apt to produce anxiety: stereotype threat, choking under pressure, and math.

Stereotype threat which occurs when an individual has perceived himself/herself as being targeted as a negative stereotype, particularly when it is relevant to completing a specific task; this often results in poor performance (Beilock, 2010; Unsworth, et al., 2005). Researchers have long recognized that stereotype threat impairs performance; however, the reason for the effects

have remained ambiguous (Schmader & Johns, 2003). Recent research suggests the cause may be due to a reduction in WMC (Schmader & Johns, 2003; Schmader, Johns, & Forbes, 2008).

Schmader and Johns (2003) tested both men and women participants on the OSPAN task, then randomly assigned them to one of two groups. The control group was told that the task measured memory, and the experimental group was told that it was a measure of math ability. The experimental group revealed no significant differences in performance between genders. However, the experimental group, which was told the task was a measure of math skills, revealed significantly lower scores on the task among women than men, supporting the stereotype that women are not as proficient at math as men are. Schmader and Johns (2003) argued that stereotype threat directed attention away from the task and consumed cognitive resources necessary to perform the task. This supports Engle and Colleagues' executive attention theory of WMC, which posits the ability to suppress irrelevant information or intrusive thoughts as being a critical component of WMC (Engle & Kane, 2004).

Choking under pressure occurs when individuals perform more poorly when they experience anxiety as a result of pressure (Baumeister, 1984; Beilock & Carr, 2001; Beilock & Carr, 2005; Beilock, Kulp, Holt, & Carr, 2004). Research suggests that anxiety produced by the pressure causes temporary depletions in WMC, and the anxiety is attributed to the inability for one to maintain attention on the task. Baumeister (1984) explains choking under pressure as a decrease in performance due to the attentional demands of the latter which disrupts execution of the task. Moreover, recent research suggests WMC may be the cognitive mechanism affected by attentional demands (Ashcraft & Kirk, 2001; Beilock & Carr, 2005).

Distraction theories have suggested that the decrements in performance were due to pressure, thus causing attention to shift away from the task, toward irrelevant cues (Beilock & Carr, 2001). Thus, the irrelevant cues (e.g., worrying or rumination) compete for attention against the pertinent information necessary for executing the task or goal. Specifically, Block and colleagues argued that the attention, which would be normally freed to the execution of the task, was diverted, leading to a reduced amount of available WMC (Beilock & Carr, 2005; Beilock et al., 2004).

In a related vein, math anxiety has been argued to reduce WMC (Ashcraft and Kirk, 2001; Eysenck & Calvo, 1992). Math anxiety occurs when an individual experiences hesitation, fear, or tension related to math due to the inability to inhibit intrusive thoughts (Ashcraft and Kirk, 2001). Ashcraft and Kirk (2001) conducted a study where participants were instructed to work simple math problems in their head while simultaneously remembering unrelated letters. The results showed that, as the number of letters to be remembered increased, the participants' math skills declined significantly. Ashcraft and Kirk posited that the dual-task procedure heightened the participant's anxiety. This resulted in a transient reduction in WMC due to the participant's inability to block intrusive thoughts, which consumed attention necessary to perform the task.

Additionally, researchers have suggested that temporary disruptions in WMC have been caused by racial prejudice (Richeson & Shelton, 2003), and stress (Klein & Boals, 2001). Eysenck and Calvo (1994) proposed the processing efficiency theory, which states that anxiety limits the ability of processing within the WM system, reducing task efficiency. The current study examines the effects of feedback and the cognitive mechanisms related to negative feedback, specifically WMC.

## *Feedback*

Though there is an abundance of research examining how feedback affects performance, the subject still remains a challenge to researchers, due to the difficulty of understanding and predicting human behavior (Wofford & Goodwin, 1990). In fact, Kluger and DeNesi (1996) concluded the results in this area to be paradoxical at best. Despite the challenges, there exists an abundance of literature with numerous theoretical perspectives on the subject. Studies have shown that providing feedback significantly changes individuals' subsequent performance (Clair & Snyder, 1979). Additionally, research has demonstrated that negative feedback produces anxiety, thus impeding performance on subsequent tasks (Cody & Teachman, 2010).

While researchers have long agreed that negative feedback affects attention, studies have yet to examine temporary fluctuations in WMC. However, the following assertions exhibit characteristics similar to the attentional demands of WM. Brockner (1979) suggested that individuals who received negative feedback on their performance and maintained self-focused attention performed significantly worse than those who were able to reallocate their attention to the task. Kluger and DeNisi (1996) argue that any shift in attention away from the task involves reallocation of cognitive resources. Similarly, Vancouver and Tischner (2004) argue that tasks requiring more cognitive resources should show greater decrements in performance if attention is shifted away from the task. According to current theories of the WM system, when attention shifts away from the task, a reduction in WMC occurs.

## *The Present Study*

The aim of the present study was to identify whether a simple manipulation, such as feedback, could temporarily disrupt an individual's WMC. Inasmuch as WMC has been

considered to be a stable trait characteristic, if the manipulation affected the participants' WMC, the results of the present study would support the notion that WMC comprises both state-variable and trait-variable characteristics.

The study examined the effects of providing false feedback to participants engaged in complex memory span tasks that required high levels of attention. Two span tasks were used in the study, the OSPAN and RSPAN, which are highly correlated ( $r_s .77$ ; Conway et al., 2002). Both tasks carry a secondary memory load in addition to the items to be remembered. The manipulation provided participants with false feedback following the first span task; each participant was randomly assigned to receive either positive or negative feedback.

The present work did not attempt to challenge existing theories about the impact of feedback on performance. Indeed, this author agrees with the findings of major contributors and existing theories regarding causes in decreased performances due to anxiety; such as, self-esteem (Brockner, 1979), motivation (Clair and Snyder, 1979), and self-efficacy (Bandura & Locke, 2003). The goal was to investigate the effects of feedback on WMC. If the results are similar to those found in other anxiety related research, the findings could shed light on the cognitive mechanisms affected by anxiety.

The first hypothesis is that the participants in the negative feedback condition would show a decrease in performance on the subsequent task. This should be the case if negative feedback induces anxiety, as with stereotype threat, choking under pressure, and math anxiety. I suggest that this effect will be due to participants ruminating on past performance, thus distracting executive attention away from the current task. The theoretical rationale for suggesting that rumination would occur is due to the literature on similar anxiety-producing

situations (Bandura & Locke, 2003; Baumeister, 1984; Beilock & Carr, 2001; Beilock & Carr, 2005; Beilock et al., 2004; Clair and Snyder, 1979).

The second hypothesis is that the participants in the positive feedback condition will show an increase in performance on the second task. The rationale for this notion is attributed to additional amount of attention available to allocate to the task. By freeing up this executive attention to focus on the task, any anxiety that would naturally occur in performing a novel task should be minimized.

A common experience for many individuals is to feel frustration when the performance is worse than expected on a relevant task, and people conversely feel good upon finding out that they have done better than expected. To elicit similar feelings in an experimental setting, the experimenter provided participants with either positive or negative feedback. However, the feedback was not an accurate reflection of the participants' proficiency; rather, it depended on the group to which they had been randomly assigned. One group of participants was told that they had done surprisingly poorly and the other group was told that they had done unexpectedly well. Immediately following the false feedback, participants completed the subsequent WM span task.

## CHAPTER 2

### METHOD

#### *Participants*

A total of 90 participants (35 male, 51 female) were recruited from the research subject pool at the University of Georgia. Participants received research credit for their participation. Each participant was tested individually in one session lasting 35-60 minutes. An accuracy criterion of 80% was set to ensure that participants were not trading off between remembering the letters and solving the problems on the OSPAN, or reading the sentences on the RSPAN. Only four participants did not meet the criterion, thus their data were excluded from the analysis, leaving a total of 86 participants for analysis.

#### *Procedure and Design*

Participants gave informed consent, and then completed a brief demographic profile. The experimenter explained that the study consisted of participants completing two working memory tasks. The participants first completed either the RSPAN or the OSPAN task, determined by random assignment. After each task was explained the participants were given trial questions to practice. Immediately following the completion of the first span task, the experimenter (falsely) informed them of their performance. The participants were randomly assigned to either the negative or positive feedback condition (N = 44) in the negative feedback group and (N = 42) in the positive feedback group.

Participants in the negative feedback condition were asked if they understood the directions, and were told that the experimenter had rarely seen a score that low. Participants in the positive feedback condition were asked if they had ever participated in a similar task and told that the experimenter had rarely seen a score that high. Following the false feedback, the experimenter informed the participants that they would be performing a similar working memory task. Participants were debriefed following the second task. As an added measure of control, the same experimenter provided the false feedback to all participants.

The design was a 2 (feedback: positive vs. negative) x 2 (task: task 1 vs. task 2) analysis of variance (ANOVA), with task as the repeated measure and the within-subjects variable.

#### *Working memory span tasks*

*Reading span.* The reading span task used was a modified computer-based version (Kane et al., 2004) of Daneman and Carpenter's (1980) original reading span task. Participants were instructed to read a sentence and determine its meaningfulness, while simultaneously they attempted to remember an unrelated set of letters. The meaningfulness of the sentence was irrelevant; the purpose was to add a second cognitive load. However, errors were examined to assure that participants were not simply ignoring the sentence and only attempting to remember the letters. Half of the sentences made sense and half did not. To create the nonsense sentence, one word was replaced (e.g., "The prosecutor's dish was lost because is was not based on fact"). In this example the word *case* was changed to *dish*. Following their reply as to whether or not the sentence made sense or not, an unrelated letter (F, H, J, K, L, N, P, Q, R, S, T, Y) was displayed for one second. The trials ranged in list length from 3-7, followed immediately by the next operation. The participants were given three practice sets containing a list of two problems.

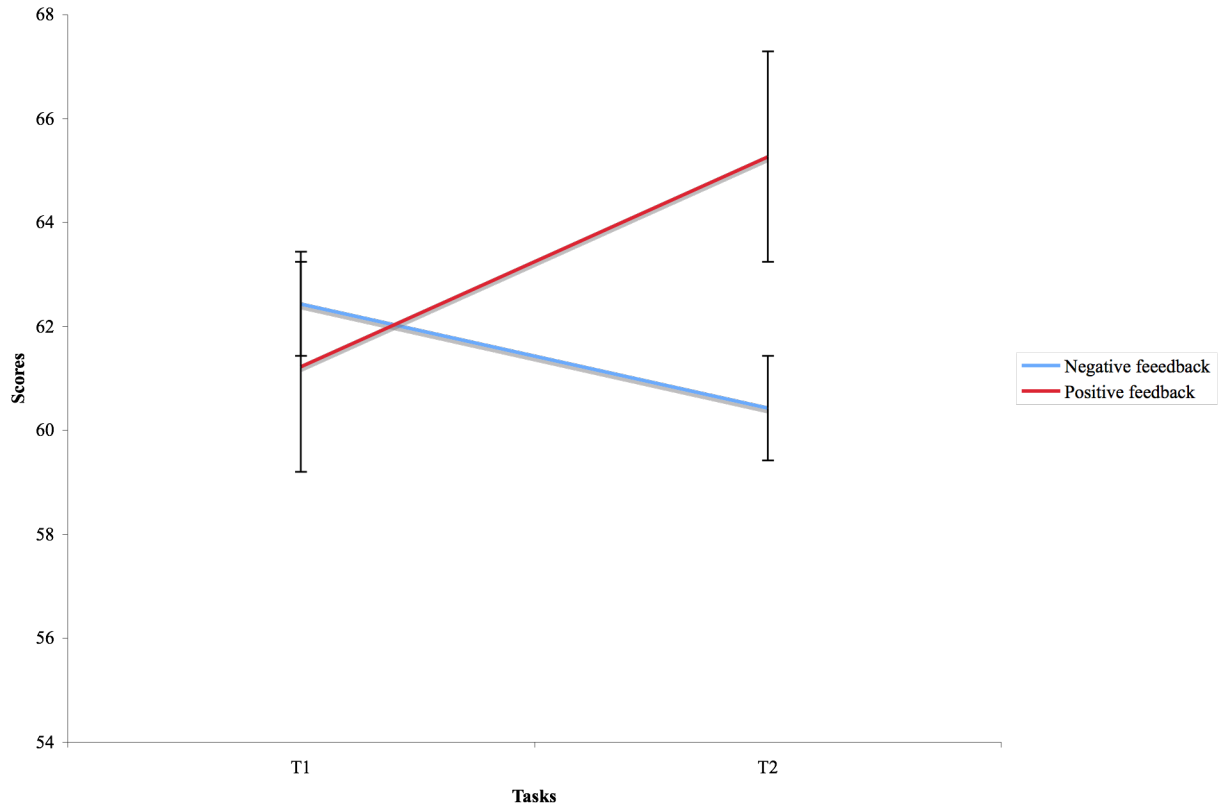
Scores were determined by the number of correctly recalled letters in the correct order, with a maximum score of 75.

*Operation span.* The participants were presented with a simple math problem (e.g.,  $12 / 3 + 2 = 6$ ) then were instructed to indicate whether or not the answer was correct, followed by a to-be-remembered letter for one second. As in the reading span, they were simultaneously attempting to recall a set of letters. Immediately following the displayed letter, the next operation began. The list lengths ranged from 3-7 and varied randomly. After each trial, participants were to recall the letters in the correct order. The participants were given three practice sets containing a list of two problems. Scores were determined by the number of correctly recalled letters in the correct order, with a maximum score of 75.

## CHAPTER 3

### RESULTS

The ANOVA revealed that feedback indeed affected the participants' WMC,  $F(2,84) = 13.56, p < .001, MSE = 54.96$ . Figure 1 reflects the significant Task x Feedback interaction. The overall mean scores of participants on the first task and second task were 62.09 (SD = 8.31, SEM = .867), and 62.86 (SD = 10.10, SEM = 1.076) respectively. As expected, participants in the negative feedback condition performed more poorly on the subsequent task following the manipulation. Similarly, as was suggested, the participants in the positive feedback condition improved their performance following the manipulation. The scores of all participants on task 1 were not significantly different,  $t(86) = p > .05$ ; however on task 2 the scores were significantly different,  $t(86) = 2.59, p < .05, SE = 1.73$ .



*Figure 1.* The effects of feedback on performance for all participants.

To further examine differences between low and high spans, the 92 participants were median divided into groups. The span scores for all participants on task 1 determined the grouping ( $M = 62.09$ ,  $SD = 8.31$ ). Participants who scored 63 or below were grouped as low spans ( $N=37$ ), and scores 64 and above were grouped as high spans ( $N=49$ ). The mean scores of the low span and high span groups were 56.00 and 68.86, respectively.

The first analysis was a 2 (feedback: positive vs. negative) x 2 (Score: task 1 vs. task 2) x 2 (Span: Hi vs. Lo) ANOVA, with task as the repeated measure and the within-subjects variable. Figure 2 clearly reflects two significant interactions. The first was a Score x Feedback as was observed in the analysis examining all participants as one group,  $F(1,85) = 6.88$ ,  $p = .010$ , MSE

= 45.5. The second was a Score x Span interaction,  $F(1,85) = 16.68, p < .001, MSE = 45.5$ . In addition, there was a main effect for Span,  $F(1,85) = 54.50, p < .001, MSE = 66.74$ .

Each span group was next broken down further, providing prolific data vis-à-vis the disparity between the subsequent performances of each group following the feedback. The low span group analysis revealed a significant interaction effect between task scores x feedback,  $F(1,32) = 4.30, p < .05, SEM = 44.58$  and additionally there was a main effect for scores,  $F(1,32) = 10.73, p < .005, MSE = 44.58$ . The ANOVA for the high span group revealed a significant interaction between span scores and feedback,  $F(1,52) = 4.38, p < .05, MSE = 41.83$ , in addition to a main effect for task scores,  $F(1,52) = 4.99, p < .05, MSE = 41.83$ .

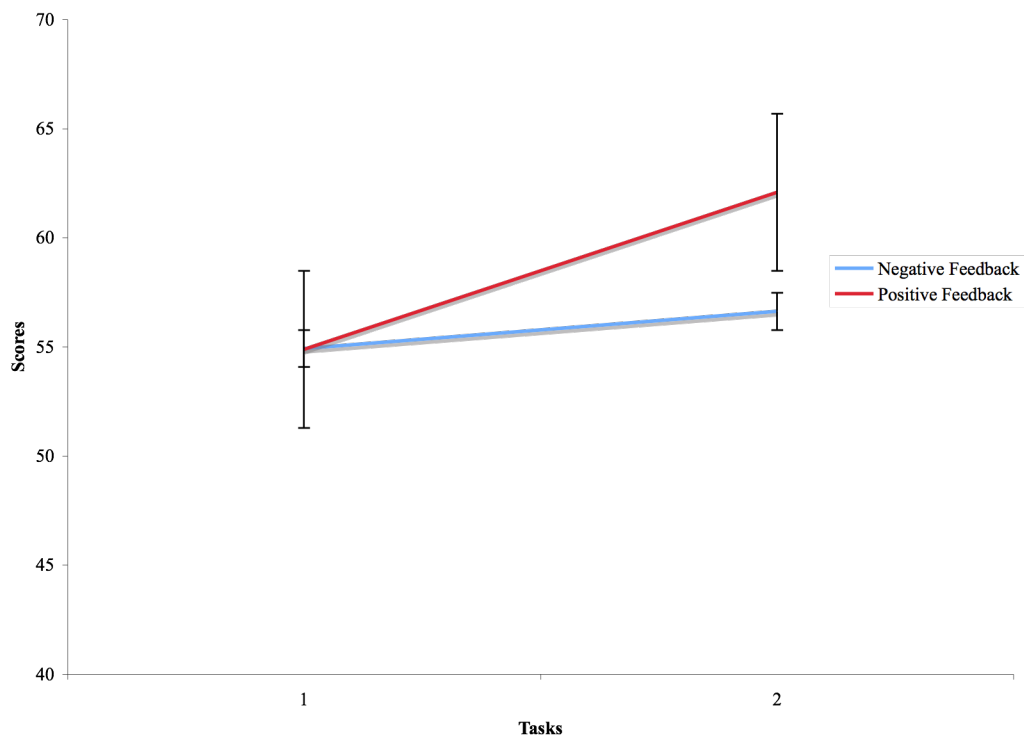
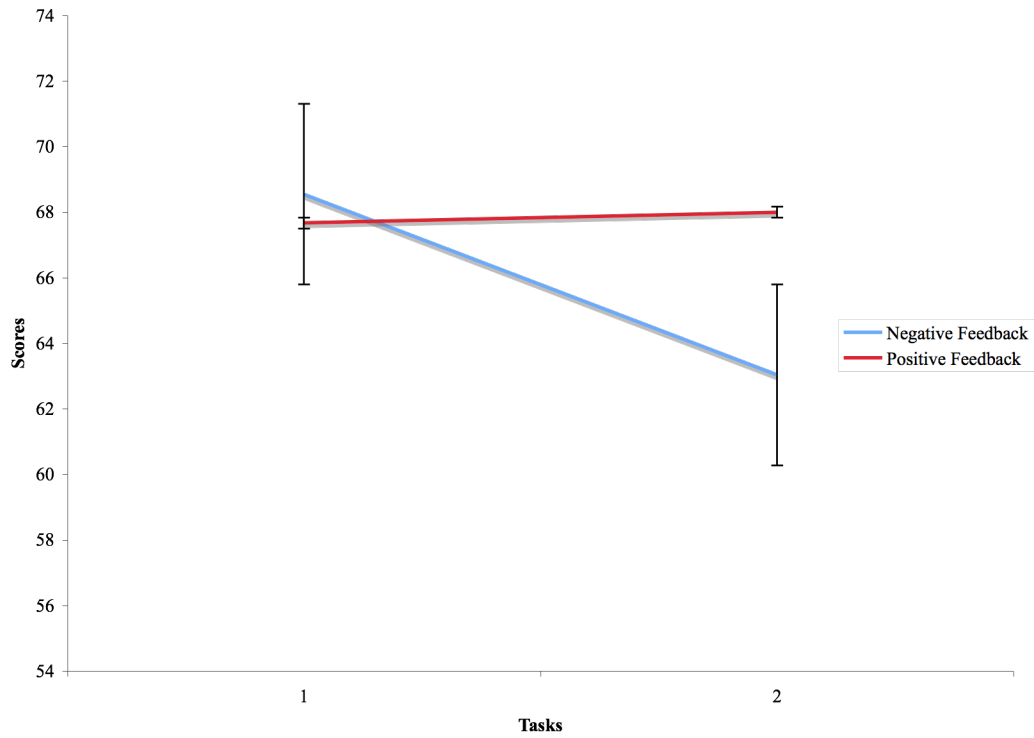


Figure 2. The effects of feedback on performance for participants in the low span group.



*Figure 3.* The effects of feedback on performance for participants in the high span group.

## CHAPTER 4

### DISCUSSION

The present experiment was designed to examine the effects of feedback on working memory, primarily to examine whether WMC is a state or trait variable. Further analysis highlighted the individual differences between high and low spans, which provided significant and novel results regarding the difference in the reaction to feedback between the groups. Indeed, the results clearly confirmed the notion that feedback had affected individuals' WMC. Working memory research has evolved to focusing mainly on the relationship of WMC and other cognitive functions or mechanisms and the individual differences between individuals with high and low span WMC; hence providing the rationale for the further analyses .

Results of the present study confirmed the first hypothesis, that the participants in the negative feedback condition would show a decrease in performance on the subsequent WM span task. These results support the previous research, suggesting that due to anxiety, WMC caused the decreased performance (Ashcraft & Kirk, 2001; Beilock & Carr, 2005; Schmader, 2010; Unsworth, Heitz, & Engle, 2005).

Novel to existing literature, the data revealed that participants in the positive feedback condition increased their performance on the second task. This confirms the second hypothesis that the participants in the positive feedback condition would perform better on the second task. These findings offer an empirical explanation to researchers studying the effects of feedback. I posit that the results found in the negative feedback condition were due to a temporary disruption in WMC, suggesting that participants ruminated on the negative feedback.

The results of the present study revealed that negative feedback produces a reduction in cognitive functions, while positive feedback increases performance among low spans. While the results of those in the positive feedback condition are novel, thus more difficult to explain, the results of those in the negative feedback condition support the notion that attention is limited in capacity and, when captured by an irrelevant distraction or intrusive thoughts, results in less attention available to focus on the goal of the task (Conway & Engle, 1994; Engle et al., 1995; Engle, Kane, & Tuholski, 1999). Furthermore, the results of this study are consistent with recent arguments that WMC has both state and trait variable characteristics.

Additionally, the results demonstrate that high spans do not increase their performance following positive feedback, but following negative feedback performance significantly decrease. The assertion that high spans utilize strategies would suggest that, following positive feedback the performance should remain constant. This is consistent with the ceiling effect, suggesting that the high spans were already performing at their potential. However, when high spans receive false feedback, a plausible argument is that the participants changed their strategy to a *second best strategy*. The results further support this notion, in that, high spans scored higher following negative feedback than did the low spans in both conditions.

If indeed low spans do not generally utilize strategies (Conway & Engle, 1994; Kane et al., 2007), it is reasonable to assume that the increase in performance is owing to the fact that positive feedback condition provided motivation to pay more attention on the subsequent task. Possibly, when low spans received negative feedback it prompted them to use a strategy in order to improve performance on the subsequent task. Regardless of speculation, the results for the low spans demonstrate the floor effect, suggesting that the performance on the first task was poor, and left room for improvement.

Another possible explanation for the results is simply a regression toward the mean. Some would argue this to be the best explanation simply because scores on a subsequent task tend to regress toward the mean, as the results in Figure 1, show.

Still, the original hypothesis remains a valid explanation for the results found between high and low spans. High spans were more apt to succeed in tasks that require higher levels of cognition; therefore, negative feedback could cause rumination on the past performance. This suggests there would be less attention available to commit to the subsequent task. In the positive feedback condition, high spans would have no need to ruminate.

To explain the results of the low spans in both conditions is more difficult. The low spans' reaction to the negative feedback perhaps didn't cause rumination due to the expectations of their performance: they are more accustomed to poor performance on cognitive tasks. Positive feedback could have eliminated any anxiety natural to performing a novel task. Or again the positive feedback may have boosted their motivation to perform better on the second task. One alternate explanation for the results of this study could be that the participants shared a similar lack of motivation, self-esteem, or some combination of the two.

## CHAPTER 5

### CONCLUSION

The findings of the present study are: (a) data revealing temporary changes in WMC contributes to the state/trait characteristic of WMC; (b) introduced feedback to existing literature which suggests that anxiety causes a reduction in WMC; (c) the results offer social psychologists with a cognitive mechanism resulting in poor performance due to anxiety; and (d) novel to WMC research, the study revealed that positive feedback may in fact increase an individual's WMC, providing researchers a venue in which to explore how positive effects may temporarily increase one's WMC.

Since individual differences were not planned for the current study opportunities were missed to gather additional information that would assist in understanding possible explanations for the performances on the second task, among both low and high spans. Future research should introduce a questionnaire following the second task, as to the usage and or changes in strategies in conducting the tasks, as well as attitudes, focus, and emotional states. In my view, to have this information would certainly help to clarify why the results were so contrastive among the spans. In addition, having the knowledge of each participant's trait anxiety level would provide further knowledge, about which this study can only speculate.

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