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When information processing is demanding: the importance of performance feedback

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ABSTRACT

Working memory is a limited component of the cognitive system that requires attentional control to store information despite internal and external interruptions actively. There is a prolonged understanding that working memory capacity is a trait variable; and emerging evidence indicates that it possesses state variable qualities (i.e. momentary oscillations). Corresponding variations have been discovered in WM-consuming situations such as stress, anxiety, and intrusive thoughts. The current study investigated such phenomena using false feedback as a manipulation to investigate transient changes in working memory capacity. Participants performed a highly correlated working memory task, preceded by manipulating either negative or positive feedback, and then completed a second closely correlated working memory task. The results indicated that the manipulation affected participants' performance on a subsequent second working memory task. Our results indicated that it is feasible to modulate the level of working memory capacity accessible on a limited basis. The findings of present study are pertinent to additional domains such as (social, educational, professional) in which information load may lead to stress and decrease working memory capacity and processing speed. The current research demonstrates the importance of feedback to enhance working memory capacity. Our study also recommends that the information load can be handled more efficiently to promote learning through different strategies.

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Working memory capacity, Performance feedback, Attentional control

INTRODUCTION

One of the most important feature of the cognitive system is working memory which allows for temporary change and manipulation (Baddeley, 2006; Rey et al. 2019) of available information. Working memory is a cognitive system responsible for actively maintaining, manipulating, and retrieving task-relevant information and maintaining a high level of regulated attentiveness. It is essential to highlight that working memory (WM) is not required when there are no distractions (Unsworth and Engle, 2009). Cognitive scientists typically differentiate between spontaneous mental functions that do not involve high levels of WM and those that involve conscious effort, which necessitates WM. Baddeley and Hitch (1974) proposed the initial model of WM, which includes two different stores: the phonological loop, which uses relatively brief storage of verbal information, and the visual-spatial sketchpad, which uses short-term storage of images. More importantly, the third component is a central executive, expected to distribute limited cognitive capacity (Baddeley and Hitch, 1974). Working memory capacity model of Cowan (1998) has contributed to the rapid growth in working memory capacity (WMC) research. The model addresses the role of attention in the WM process; and cognitive scientists still employ this model. Cowan's (1988) model of the WM system explored the inclination of research from the structures of WM to its functions (Cowan, 1988; Engle, 2010; Heitz and Engle, 2007) among others.

Numerous researchers believe that working memory can be alienated by separate mechanisms to store visual and verbal information. Regarding visual short-term memory, researchers using change-detection tasks have provided practical exhibitions and explanations that a limited amount of information (Adam et al. 2017; Vogel, Woodman, and Luck, 2001) can be perpetuated in visual working memory autonomously of the number of features probed for each object. Using rapid rates of stimulus presentation, diverse components of visual working memory have been examined. These researchers believe that encoding information into working memory is temporally and cognitively demanding (Gruszka and Necka, 2017) and several other researchers.

Perceptible and functional persistence both maintain precision (Gmeindl, Jefferies, and Yantis, 2020; Irwin and Thomas 2018) reported high-capacity, point-by-point retinotopic sensory traces that decay rapidly following a stimulus event. The initial model proposed by Baddeley (1974; 2000) remains the most critical and vital model in working memory research. The model primarily consists of two systems, domain-specific and domain-general. In connection to modalities, the systems were categorized; domain-specific systems were divided into the phonological loop, and visual-spatial sketch pads, according to modality information, are often called modality-specific systems (Botta et al., 2019). Researchers believe that each subsystem of modalities has separate and independent capacity limited storage for the temporal retention of verbal or visual-spatial information (Sorqvist, Stenfelt and Ronnberg, 2012). The study by Yang et al. (2019) support that these subsystems are not independent and are composed of the central executive, a general-domain system. Pearson (2019) and several other researchers have discovered that mental imagery and cognitive style play an essential role in memory and motivation. To perform higher executive functions such as reasoning and language, temporary storage and manipulation in verbal working memory allows units of linguistic information to be modulate based on sensory persistence. In addition, both verbal and visual modalities refresh phonological store content (Sghirripa et al. 2021; Hu et al. 2019). In reference, the way information crosses the phonological loop depends upon the modality of appearance both the modalities, function and process following the information presented and perceptual pathways. Visually presented stimuli in working memory require rapid information conversion from the visual to phonological system (Czoschke et al. 2019). Conversely, verbally presented stimuli had a more undeviating route to phonological coding.

Traditionally WM capacity has been understood as a trait variable Ackerman, Beier, and Boyle (2005) Engle and Kane (2004). According to Engle and Kane (2004), working memory capacity is an enduring attribute of an individual, indicating that it is persistent and constant and thus does not fluctuate throughout an individual's life (Conway et al. 2005). Studies have examined the cognitive mechanisms involved in anxiety-related performance decline. WMC is supposed to cause decreased performance (Beilock and Carr 2005; Engle 2010; Kane et al. 2007; Schmader 2010) and others. In addition, a series of studies by Schmader and Johns (2003) found that a transient decline in the WMC cause underperformance.

Research proposes that anxiety caused by pressure induces transitory depletions in WMC, and anxiety is associated with an inability to focus on the task. Research shows that strangling under pressure results in decline in performance caused by the attentional demands of the hindmost and disturbs task execution. Furthermore, new research by Comishen and Bialystok (2021), Wileyand Jarosz, (2012), suggests that WMC may be the cognitive mechanism modulated by attentional demands. The processing efficiency theory, proposed by Eysenck and Calvo (1994), states that anxiety restricts the WM system from processing information, reduces working efficiency. The present study examined the effects of feedback and cognitive mechanisms associated with negative feedback, specifically working memory capacity.

Performance feedback

Research shows that providing feedback impacts an individual's subsequent performance (Clair and Snyder 1979). Furthermore, research has shown that negative feedback causes anxiety, impairs performance on later tasks (Cody and Teachman 2010). The role of feedback in problem solving and learning has been extensively researched by Kleij et al. (2015); Hale and Stanney (2014) and other researchers.

Feedback in learning environments consists of information that enables learners to confirm, ignore, or improve their prior knowledge. Generally, feedback benefits are significant and beneficial; motivate many academics to promote its use (Hattie and Yates 2013; Steedly et al. 2008). Indeed, Wisniewski et al. (2020) identified feedback as one of the classroom's most valuable influencers on performance. Although experts have long believed that negative feedback affects attention, research on temporal variations in working memory capacity has not yet been conducted. Research reveals that any transference of attention from a task demands the reorientation of cognitive resources (Vancouver and Tischner 2004).

Nature of feedback can better understood by investigating the effect of working memory capacity as a potential moderator. Monitoring and evaluating feedback relies heavily on working memory capacity. Theoretical feedback models (Clariana et al. 2000; Pan and Rickard 2018) are involved in internal cognitive abilities such as working memory which may influence how feedback is received and processed. Gal and Hershkovitz (2021) proposed that the learner engages in cognitive processing to analyze the information and produce a response at each task stage (i.e., initial question, feedback, later question). It includes linking elaborative feedback to the initial response, consolidating the existing knowledge, and evaluating progress. All of this processing is highly dependent on working memory capacity

Current study

The current study was designed to determine if a simple manipulation, such as performance feedback, might potentially disrupt an individual's working memory capacity. It is believed to be a static trait feature; nevertheless, if the manipulation influenced the participants' working memory capacity, the findings of this study would support the concept that WMC consists of both state and trait-variable attributes. Our first hypothesis is that participants in the negative feedback group would decline performance on the consequent task. The second hypothesis is that participants in the positive feedback group will improve performance on the second task.

METHODOLOGY

Participants

A total of 58 students from different coaching institutes participated in the study. Of 56 participants (37 male, 21 female), 12 were left-handed, and 46 were right-handed subjects. The participants were not having any psychological or neurological conditions and reported 20/20 uncorrected or corrected vision. Two participants did not complete all the tasks, their data were removed from the study, leaving 56 participants to be analyzed. Participants gave informed consent before participation in the experiment.

Measures

Personal datasheet

The personal data sheet was designed to help the researcher have the respondent's background and demographic information. Only participants studying in coaching institute were recruited to bring homogeneity in the sample. The sheet consists of age, gender, educational qualification, and schooling. All the demographic information was collected through Google form to get basic details about the participants in study.

Experimental procedure and design

The task was presented in PsychoPy v3.0 (https://www.psychopy.org/). The participants were tested individually. The assignment to conditions was on a random basis. Before presenting a task, the participants were informed about the task and doubts were cleared before the task started. The researcher stated that participants in the study had to complete two working memory tests. The participants began by completing either the Reading span or the Operation span tasks assigned at random. Following an explanation of each activity, participants were given 8 trials as a practice session. Participants were randomly allocated to negative or positive feedback conditions (n = 34 in the negative and n = 22 in the positive feedback groups). The participants received performance feedback in written from (e.g. "3 correct"). 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 ("cumulative score e.g. 43"). 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. Afterwards, the participants were acknowledged for their participation in the study.

Working memory tasks

Reading span task

The reading span task used was a modified computer-based version (Engle et al., 999; Kane et al., 2004). Participants were advised to read a phrase and evaluate its meaning while recalling an irrelevant sequence of letters sequentially. The paragraph's meaning was irrelevant; the goal was to create a second perceptual load. However, errors were evaluated to ensure that participants were not just neglecting the phrase and attempting to recall the letters. Only half of the statements made sense, and the rest of the half was nonsense. One word was replaced to make a nonsense phrase. After their response about whether or not the sentence made sense, a random letter (G, J, L, P, Q, I, Y) was presented for 1000 ms. Performance is measured by scoring responses to the trials and the time (ms) taken during recall.

Operation span task

The operation span task requires the participants to remember the visually presented stimulus. A simple arithmetic operation was presented to the participants and was asked to identify whether or not the response was accurate, followed by 1000ms to remember the letter. They were attempting to recollect a series of letters at the same time as they were reading. The next operation began shortly after the displayed letter. Participants were asked to recall the letters in the correct sequence after each trial. 3 training sets, including a set of two operations, were distributed to the participants. The number of adequately recalled letters in the correct order estimated the score, with a maximum score of 74.

Scoring procedure

The recall task results were scored according to the all-or-nothing method (Conway et al., 2005; Friedman and Miyake, 2005). A total of the correct recall items from each block is counted as a proportion of that block. The WM scores are then averaged to come up with the final WM score, which can range from 0 to 1. To analyse data we used the Statistical Package for Social Sciences SPSS 22 (https://www.ibm.com/in-en/products/spss-statistics).

RESULTS

Working memory performance results for the reading and operation span task are described in the Table 1. Skewness and kurtosis values < 2 indicate that the distribution is normal (Bai and Ng, 2005). To calculate Cronbach's alpha, we computed the proportion of internal consistency between individual blocks recalled correctly (Conway et al., 2005). Internal consistency for the administered tasks was very high, proposing that all blocks contributed to the equal quantities to the individual scores.

Table 1. Illustrates the descriptive statistics of reading and operation span task

Task	Mean	SD	Skewness	kurtosis	Cronbach's Alpha
Reading span	0.82	0.12	-0.16	-0.61	0.93
Operation span	0.95	0.09	-0.66	-0.14	0.95

The Analysis of Variance revealed that participant's working memory capacity was affected by performance feedback, $F(2,54) = 11.56$, $p<.001$, MSE = 53.66. The [Task x Feedback] connection is depicted in Figure 1. Participants' overall mean scores on the first and second tasks were 61.09 (SD = 7.31, SEM =.867) and 60.86 (SD = 9.10, SEM = 1.067), respectively.

Participants in the negative feedback condition performed poorly on the subsequent task after the manipulation, as expected. Similarly, as hypothesized, participants in the positive feedback condition enhanced their performance after the manipulation. All participants' scores on task 1 were not significantly different, $t(56)$ = p >.05, SE = 3.25 nevertheless, the scores on task 2 were significantly different, $t(56) = 2.49$, $p<.05$, SE = 1.72.

The 56 participants were divided into groups to investigate the differences between low and high spans. The grouping was represented by the span scores of all participants on task 1 (M = 61.09, SD = 8.21). Participants who scored 62 or lower were classified as low spans (n=21), while those with 63 or greater were classified as high spans (n=35). The low span and high span groups had mean scores of 56.00 and 68.86, respectively.

The primary analysis was a 2 (feedback: positive vs. negative) x 2 (Score: task 1 vs. task 2) x 2 (Timespan: high vs. low) ANOVA, utilizing task as the repeated measure and timespan as the within-subjects variable.

As Figure 2 clearly illustrates two vital interactions. The first was a Score x Feedback, as seen in the analysis of all participants as a single group, $F(1,55) = 6.86$, p =.010, MSE = 44.5. Second interaction was a Score x Timespan $F(1,55) = 16.67$, p<.001, and MSE = 46.5. There was also a major impact on timespan, $F(1,55) = 53.50$, p<.001, MSE = 66.73.

Each timespan group was then subdivided to display the difference between each group's subsequent performances following feedback. The low timespan group analysis revealed a significant interaction effect between task scores and feedback, $F(1,21) = 3.30$, p<.05, SEM = 44.57, and a main effect for scores, $F(1,21)$ =10.72, p<005, MSE = 44.57. In the high span group, the ANOVA showed the significant interaction between span scores and feedback, $F(1,35)$ = 4.36, p<.05, MSE = 41.82, as well as a main effect for task scores, $F(1,35) = 4.99$, p<.05, MSE = 41.73. Figure 3 illustrates the graphical representation of high span group.

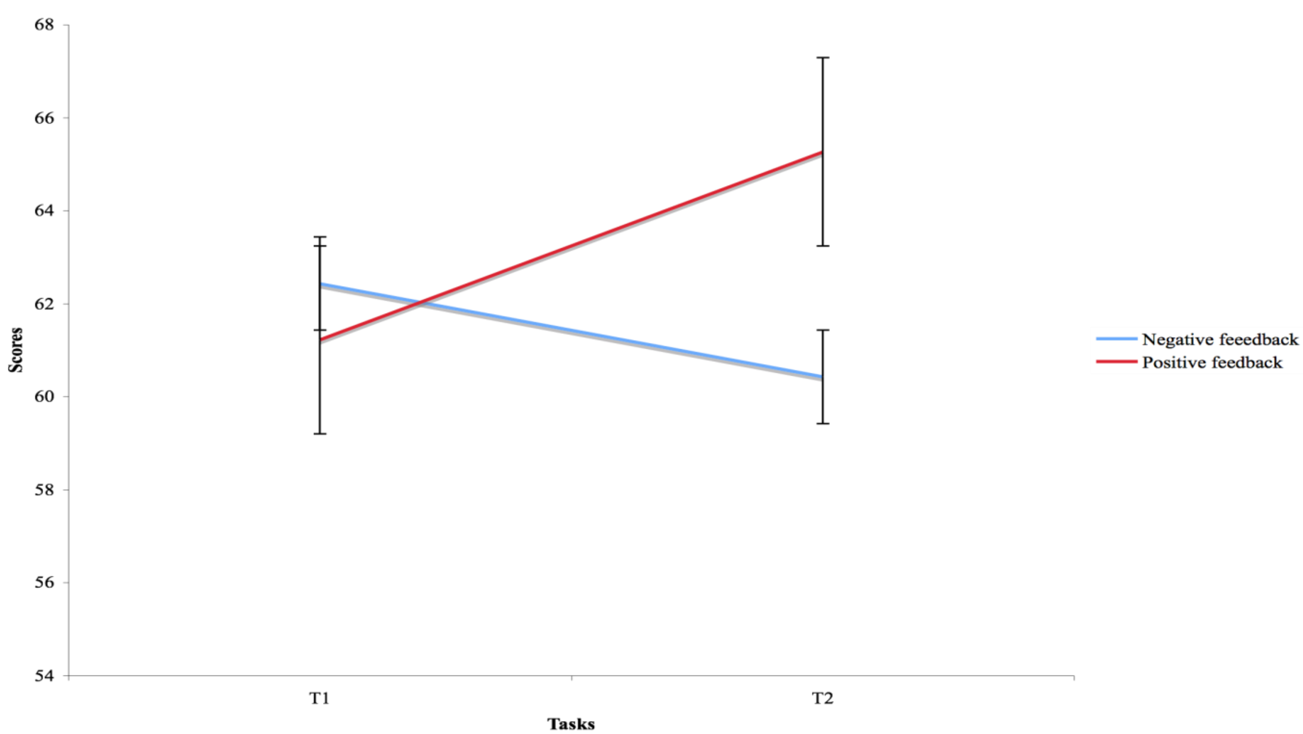

Figure 1. Illustrates the effects of feedback on all respondents' performance in operation and reading span tasks

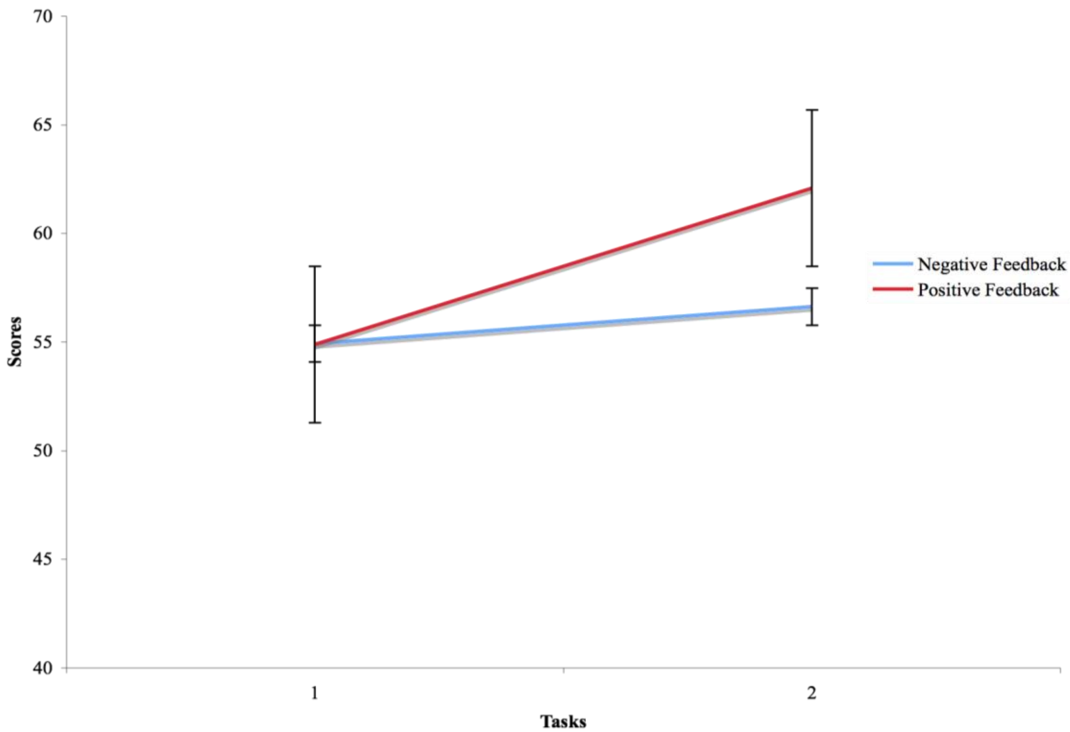

Figure 2. Shows the effects of feedback on performance for subjects in low span group

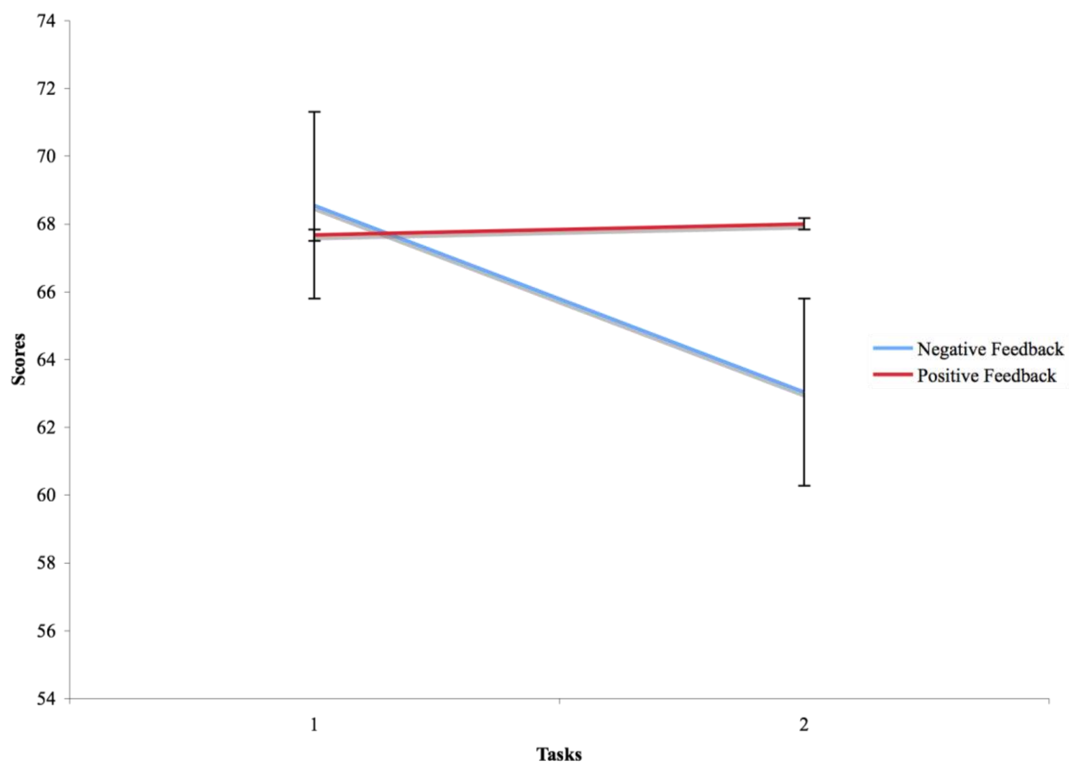

Figure 3. Depicts the impact of feedback on performance in the high span group

DISCUSSION

The present study was designed to investigate the impact of feedback on working memory, specifically whether working memory capacity is a state or trait variable. Further examination revealed individual variations between high and low timespans, provide significant and unique insights about the difference in responsiveness to feedback between the groups. Nevertheless, the findings demonstrated that feedback affected individuals' WMC. Working memory research has grown to focus primarily on the connection between WMC and other cognitive functions or systems and the individual variations between persons with high and low span WMC, therefore giving a framework for future analyses. Our results confirmed the first hypothesis that participants in the negative feedback condition would display decreased performance on the subsequent span task. The results support earlier studies, (Kim, 2020; Senko et al. 2011; Cowan et al.; 2005) indicating that working memory capacity reduced performance due to stress and anxiety

The findings showed that participants in the positive feedback condition improved their performance on the second task, which was novel in the existing research. The results support the second hypothesis that participants in the positive feedback condition would execute better on the second task. The outcomes of our study will provide an empirical explication for researchers examining the role of performance feedback. We believe that the results obtained in the negative feedback condition were due to a brief interference in working memory capacity (Fong et al. 2019; Walcott, 2013) implying that individuals contemplate the negative performance feedback.

The current study found that negative feedback reduces cognitive functions, whereas positive feedback improves the short attention spans of participants. The results of the negative feedback condition support the notion that attention is limited in capacity and that when captured by an irrelevant distraction or intrusive thoughts, there is less attention available to focus on the task's goal (Ziegler et al. 2019; Nikolla et al. 2018; Kane et al. 2007). Furthermore, the findings of this study support previous claims that WMC possesses both state and trait variable features (Moran, 2016; Ilkowska and Engle 2010; Johnson, and Gronlund 2009). Moreover, the data show that high spans do not improve their performance after receiving positive feedback, while their performance sustains considerably after receiving negative feedback. The assumption that high spans use techniques would imply that after positive feedback, performance should be constant. It is consistent with the ceiling effect, indicating that the high spans already operate at total capacity (Lukasik et al. 2019; Nieuwenstein et al. 2009; Vogel and Luck 2002). Suppose low spans do not use strategies in general. In that case, it is logical to believe that the performance improvement is attributable to the fact that the positive feedback condition generated resources (Loaiza, Doherty and Howlett, 2021; Diamond 2013; Kane et al. 2007) to bring greater attention to the subsequent task. When those with short attention spans received negative feedback, it may have encouraged them to formulate a strategy to improve their performance on the next task. Regardless of assumption, the outcomes for the low spans show the floor effect, implying that performance on the first task was poor and could be improved (Frederick 2000).

The original hypothesis maintains a reasonable explanation for the findings obtained between high and low timespans. High spans were more likely to be successful in activities requiring higher levels of cognition; hence, negative feedback might lead to ruminating about prior performance. It implies that there would be less focus available to concentrate on the next activity. High spans would not need to contemplate in the positive feedback state. Positive feedback might have alleviated any anxiety generated from performing an unfamiliar task (Cooke et al. 2021; Bohndick et al. 2020). Furthermore, positive feedback might have strengthened their ability to perform better on the second task (Li et al. 2020; Van Dijk and Kluger 2011). OneF possible explanation for the study's outcomes is that the respondents shared an identical lack of motivation, self-esteem, or a mixture of the two.

CONCLUSION

The findings of present study reflect that data exhibiting transitory variations in working memory capacity contributes to the state/trait feature of working memory capacity; proposed feedback to prior literature stating that anxiety leads to a reduction in WMC. The study revealed that positive feedback might increase an individual's WMC, providing researchers with a direction to investigate how positive effects may temporarily increase individuals WMC. In addition, the study also recognize the importance of pedagogy of learning in connection to performance feedback.

Future studies should incorporate subjective methods to evaluate the changes in task strategies, mind-set, attentiveness, and emotional state during the execution of the task. Such information, in my opinion, would likely assist in knowing why the results were so diverse across the spans. Besides, identifying each individual's trait anxiety level would disclose further performance information.

DECLARATION

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Authors' contribution

The corresponding author contributed in conception and design of the study, data collection, drafting and editing in the manuscript. Khan ShM analyze and interpret the data, and also critically revise the manuscript and final approval of the manuscript. All authors reviewed the results and approved the final version of the manuscript.

Conflict of interests

The authors state no conflict of interest.

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