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The Role of Working Memory in Problem-solving and Decision-making

Umm e Hani Zafar[1], Fazeela Arshad[2], Abeera Karamat[3], Umar Hayat[4], Zainab Kausar Khan[5], Tehmina Ashraf[6]

Abstract

The role of working memory in problem-solving and decision-making is crucial, especially among students, as these cognitive processes are essential for learning and academic success. This study was aimed at investigating the role working memory in decision making and problem solving abilities among students. Correlational research design was used to conduct this quantitative research. Survey was administered with closed ended questionnaires as method of data collection. Convenient sampling technique was employed to select the sample of study 100 (male=50, female=50) students. Findings of the study reveal that working memory positively correlated with problem solving ability and decision making. Male reported greater level of working memory, problem-solving and decision-making abilities as compared to female. By improving and optimizing working memory, individuals can enhance their ability to solve complex problems and make better decisions, especially when under pressure. Students must improve their level of working memory to solve complex educational problems.

Keywords: Working memory, decision making, problem solving

1. Introduction

Working memory (WM) refers to the cognitive system responsible for temporarily storing and manipulating information required for complex tasks such as learning, reasoning, problem-solving, and decision-making. It allows individuals to hold and process relevant information, enabling them to focus on a task, update their knowledge in real-time, and use that information to make decisions. Research has consistently highlighted the importance of WM in both problem-solving and decision-making. Studies convincingly demonstrate that WM, especially the central executive of WM, plays an important role in solving insight problems and other creative tasks (Chuderski & Jastrzębski, 2018a; Smirnitskaya & Vladimirov, 2017). A number of studies have also shown that modal-specific WM storages are primarily important for solving insight problems, in particular the visuo-spatial sketchpad for visual insight problems and the phonological loop for verbal insight problems (Chein & Weisberg, 2014). This evidence is most often cited in support of the non-specific approach, which postulates that insight does not entail any special processes that would distinguish it from the solution process of non-insight problems. In other words, the solution of insight and non-insight problems relies on the same analytic processes of heuristic search. At the same time, executive control and WM have been shown to be either less important or even detrimental for insight problem solving (Xing et al., 2019; Khan, 2020). This idea relies on the concept of insight as overcoming an impasse through representational change. In this case, executive control and overconcentration might inhibit representational change. Therefore, loading WM or redirecting attention or control may facilitate the solution of an insight problem. Recent studies revealed the low reproducibility of experiment results which had supported a positive correlation between WM loading or executive control distraction and insight solutions (Drążyk et al., 2020; Russo, 2022).

Modern research in psychology of thinking tends to move away from analyzing the process of insight problem solving towards analyzing insight itself (Moroshkina et al., 2020). Recent studies demonstrated that the cognitive load on WM does hinder insight solutions to some, but a much lesser extent, than analytic solutions of a single set of Compound Remote Associates tasks (Stuyck et al., 2022). Several approaches to analyzing problem solution stages have been proposed. The first aims to reduce the proportion of analytic processes in insight problem solving. Ash and Wiley (2006) suggested that the demand for WM is greater during the first stages of insight problem solving, when the solver is dealing with the initial incorrect representation using analytic solution methods, whereas the final restructuring stage that involves representational change is not as WM-heavy. The authors developed a set of insight problems, each of which exists in two variants: actions within the initially incorrect representation are either available (many moves available, MMA) or limited (few moves available, FMA). Experiments with these problems demonstrated that the overall WM performance predicts a successful solution of MMA problems, which involve both the search and the restructuring stages. At the same time, WMC is not a predictor of success for FMA problems, in which representation change is the key stage. Based on these findings, the authors conclude that the restructuring or representation change does not require executive control and relies on automatic processes such as redistribution of activation. However, a recent study by Chuderski & Jastrzębski (2018b) showed that the number of available actions within the initial representation does not affect either objective or subjective indices of insightful solutions. After a large number of participants had solved problems with either a little or a large number of available actions within the initial representation, Chuderski and Jastrzębski found no consistent variation in success rates, self-reported experiences, or fatigue between these two problem types. The resulting correlations points at WM contribution to the solution of both types of problems. Therefore, evidence from this study disproves the idea that WM is linked only to the solver's development of an initially incorrect representation. It follows that insight problems with a different number of available moves within the initial representation are not, at this point, very useful for analyzing the role of WM at different solution stages. The second approach aims to identify and influence local events that might be linked to insight.

Yeh et al. (2014) analyzed the link between individual WM values and the developments in attention in the process of problem solving. Participants solved creative problems with graphically represented objective situations. To measure the participants' WM, researchers asked them to remember graphically represented objects. After analyzing protocols and eye movement patterns, the authors loosely identified the following three stages of problem solving: the initial stage (the first 5 seconds), the final stage (the last

[1] City College of Science and Commerce, University Campus, Multan, Pakistan, umehanizafar03@gmail.com
[2] City College of Science and Commerce, University Campus, Multan, Pakistan, fazeelaarshad23@gmail.com
[3] Bahauddin Zakariya University Multan, Pakistan, abeera3kay@gmail.com
[4] Ph.D Scholar Department of Business and Administration, NCBA&E Sub Campus, Multan, Pakistan, umarhayatrehmani786@gmail.com
[5] Lecturer City College of Science and Commerce, University Campus, Multan, Pakistan, zainabkhank520@gmail.com
[6] City College of Science and Commerce, University Campus, Multan, Pakistan, maharumair03@gmail.com

4 seconds), and the intermediate stage (time between the other two stages). This study revealed that at the intermediate stage participants with a greater WMC directed their gazes to the target objects (a part of the solution) more often and for longer periods of time than participants with a smaller WMC. Moreover, participants with a greater WMC demonstrated more frequent saccades toward the target object at the final stage.

Lv (2015) studied the involvement of WM and inhibitory control functions at different stages of insight problem solving. Based on verbal protocols, problem solving was divided into two stages: initial solution search and restructuring. The author analyzed correlations between WM tests and inhibitory control functions and demonstrated that a greater WMC shortens the initial solution search stage, while active inhibition helps to concentrate on the task, just like in analytic solutions. The restructuring stage is more closely linked to spontaneous inhibition. Depending on the problem, spontaneous inhibition can have two effects and either suppress the initially constructed wrong representation and facilitate restructuring or suppress alternative interpretations and prevent insight. Of the three approaches mentioned above, the latter is the most developed. One practical application of this approach in insight problem solving is the method of monitoring WM dynamics with a probe task (Korovkin et al., 2014). Most studies (Korovkin et al., 2016) have also demonstrated that in the case of insight problems that involve choosing from several alternatives, the solver's WM load peaks just before the answer is found. This increase in the WM usage that precedes a solution may indicate that WM, in particular executive control, contributes to insight.

Savinova (2020) explored the causes of this increase in the WM load at the last stage of insight problem solving. Consistently ruling out possible explanations (fatigue, verbalization, and analytic reasoning), the author concluded that this WM load increase is related to representational change. Korovkin et al. (2018) implemented the dual-task method to demonstrate the importance of modal-specific processing in visual and verbal insight problem solving. Problem-solving is the process of identifying solutions to complex or novel situations. Effective problem-solving often requires maintaining and manipulating multiple pieces of information, which directly engages WM. The central executive component of WM, responsible for controlling attention and coordinating the activity of other cognitive processes, plays a key role in problem-solving tasks (Baddeley, 2000; Rahat & Hayat, 2020).

Miyake et al. (2000) focused on the role of WM in complex cognitive tasks and found that individual differences in WM capacity were correlated with problem-solving ability. Individuals with higher WM capacity were able to perform better in tasks requiring the integration of multiple pieces of information and the evaluation of potential solutions. Turner & Engle (1989), they examined the relationship between WM and complex reasoning. Their findings indicated that individuals with greater WM capacity could process more information simultaneously, which is crucial for solving complex problems. WM is used to store and evaluate potential solutions or strategies during the problem-solving process. It helps in sequential reasoning and guiding actions toward a solution (Klein et al., 2017). Shamosh & Gray (2008) this study found that individuals with higher WM capacity tend to make more rational decisions. High-WM individuals are better able to consider multiple variables, leading to more accurate judgments and fewer biases. Baddeley et al. (2002) in their study, they explored how WM is linked to decision-making in ambiguous contexts. They concluded that individuals with better WM function were more capable of resolving ambiguity and considering alternative perspectives when making decisions. Research has shown that individuals with better WM are more capable of delaying immediate gratification for a better long-term outcome (Mischel et al., 1989), which is a key feature of sound decision-making. Both problem-solving and decision-making rely on cognitive flexibility and the ability to manage cognitive load. WM's role in cognitive flexibility allows individuals to switch between different problem-solving strategies or adjust decisions based on new information, thereby optimizing outcomes in both domains (Zhang et al., 2014). In problem-solving tasks, decision-making plays a critical role in selecting among multiple approaches or solutions. Poor decision-making due to limited WM capacity may lead to suboptimal problem-solving strategies, resulting in inefficiency or failure to find the most effective solution (Gilbert et al., 2005).

1.1. Research Gap

The role of working memory in problem-solving and decision-making is crucial, especially among students, as these cognitive processes are essential for learning and academic success. While there has been substantial research on working memory and its relationship with cognitive tasks, there remain several research gaps in understanding its specific role in student problem-solving and decision-making processes. There is a need for study that examine how working memory impacts problem-solving and decision-making in different subject areas (math, science, literature, etc.) and tasks that students regularly face in educational settings.

1.2. Statement of the Problem

Working memory plays a crucial role in cognitive functions, particularly in problem-solving and decision-making. These cognitive processes often involve the active manipulation and retention of information in real-time to make judgments, generate solutions, and plan actions. However, the exact mechanisms by which working memory influences problem-solving and decision-making remain poorly understood. Researcher's aim to explore how the capacity, efficiency, and flexibility of working memory impact an individual's ability to solve complex problems and make optimal decisions. Furthermore, there is a need to investigate how working memory interacts with other cognitive functions, such as attention, reasoning, and long-term memory, in shaping decision outcomes. Understanding these relationships is essential for improving interventions in domains like education, clinical settings, and business decision-making, where problem-solving and decision-making are pivotal. This research is important because it seeks to bridge gaps in knowledge about cognitive processes that underlie everyday tasks and high-stakes decisions, with implications for enhancing performance in various domains, including personal, academic, and professional settings.

1.3. Rationale of the Study

The role of working memory in problem-solving and decision-making is critical in educational contexts as it influences how students process, manipulate, and retain information while engaging in cognitive tasks. In the study of education, understanding this role provides insight into the mechanisms behind learning and academic performance. Students constantly rely on working memory to solve problems, make decisions, and learn new content. Understanding how working memory capacity impacts problem-solving and decision-making can help educators design interventions that reduce unnecessary cognitive load, thereby improving student outcomes. Problem-solving and decision-making require students to actively engage in processes such as identifying the problem, evaluating possible solutions, predicting outcomes, and reflecting on the results. These processes are heavily dependent on working memory to hold intermediate results, compare alternative strategies, and adjust approaches based on new information. By examining the relationship between working memory and these cognitive functions, the study will highlight the crucial role that working memory plays in shaping students' problem-solving and decision-making abilities. In sum, rationale of this is to better understand the crucial role of working memory in educational settings, specifically how it supports problem-solving and decision-making, and to use this knowledge to inform practices that promote student learning and academic success.

1.4. Objectives of the Study

- To investigate the relationship between working memory, problem-solving and decision-making
- To compare the mean score difference in term of working memory, problem-solving and decision-making with respect to gender

1.5. Significance of the Study

Cognitive Capacity and Information Management: Working memory is crucial for holding and manipulating information in real time. When solving problems or making decisions, individuals rely on their ability to keep relevant data in mind while weighing options, testing hypotheses, or drawing conclusions. Research in this area helps clarify how we handle competing information, manage tasks with limited cognitive resources, and focus attention when making decisions.

Problem-solving Efficiency: Working memory directly impacts how efficiently we solve problems. It allows us to break down problems into manageable parts, keep track of intermediate steps, and make connections between concepts. Studies show that individuals with better working memory often perform more efficiently in tasks that require logical reasoning, planning, and abstract thinking.

Decision-making under Uncertainty: In complex decisions, where risks, benefits, and potential outcomes must be evaluated, working memory allows for the integration of past experiences and current goals to make informed choices. Working memory helps maintain and adjust strategies in uncertain situations, balancing short-term rewards with long-term consequences.

Executive Functions: Working memory is a key component of executive functions, which control higher-level cognitive processes like attention, inhibition, and cognitive flexibility. These functions are essential for problem-solving and decision-making, as they allow individuals to shift strategies, suppress irrelevant information, and focus on important elements of a decision.

Educational and Clinical Implications: Understanding how working memory influences cognitive tasks can improve educational strategies and interventions for individuals with working memory deficits (e.g., children with ADHD or adults with cognitive impairments). It could lead to tailored approaches for enhancing problem-solving skills and decision-making abilities in various populations. Studying working memory's influence on problem-solving and decision-making deepens our understanding of human cognition, aids in developing more effective educational and therapeutic interventions, and has practical applications in everything from business decision-making to clinical diagnostics.

2. Method

2.1. Participants

Correlational research design was used to conduct this quantitative research. Survey was administered with closed ended questionnaires as method of data collection. Convenient sampling technique was employed to select the sample of study 100 (male=50, female=50) students.

2.2. Instrument

The Working Memory Questionnaire: The Working Memory Questionnaire (WMQ) was completed by the participants themselves, as a self-assessment questionnaire (Vallat-Azouvi et al., 2012). The WMQ included 30 questions, in three different domains of 10 questions each, but the questions were presented in a fixed, pseudo-random order, so that questions relating to a given domain were not presented successively, to avoid any response bias. The first domain was short-term Storage, corresponding to the ability to maintain information in short-term memory for a short period of time. The second domain was Attention, including questions on distractibility, mental slowness, mental fatigue, or dual-task processing. The third domain was related to Executive aspects of working memory, such as decision making, planning ahead, or shifting. Each question was rated on a five-point Likert-type scale, ranging from 0 ("no problem at all") to 4 ("very severe problem in everyday life"). Three sub- scores were computed, for each of the three domains (maximal score 40 for each), as well as a total score (out of 120). Higher scores corresponded to more difficulties/complaints.

Independent-Interdependent Problem-Solving Scale: Participants respond to each item using a 7-point Likert-type response scale anchored Strongly Agree and Strongly Disagree. Five of the items measure the preference for independent problem-solving (items 1, 3, 4, 8, & 9), and five measure the preference for interdependent problem-solving (items 2, 5, 6, 7, 10). Rubin et al. (2012) reported evidence of the reliability and validity of Version 1 of the IIPSS. In summary, the scale has good reliability, with a single factor structure (eigenvalue = 3.96) and good internal consistency (αs = .77 & .80). More recent and extensive evidence of the IIPPS's reliability and validity has been provided by Santakar and Rubin (2023).

3. Results

Table 1: Shows the relationship between Working Memory in Problem-solving and Decision-making

Variables	Working Memory	Problem-solving	Decision-making
Working Memory	1	.784**	.659**
Problem-solving		1	.751**
Decision-making			1

Table 1 describes the correlation among working memory, problem-solving and decision-making. Results of the study depict that working memory positively correlated with problem solving ability and decision making.

Table 2: Mean score difference of working memory, problem-solving and decision-making (n=100)

Variable	Gender	N	M	Std.Deviation	df	t-test	p-value
Working memory	Male	50	9.7612	6.94923	98	9.053	<.001
	Female	50	7.5093	5.09213			
Problem-solving	Male	50	23.9812	7.70305	98	11.701	<.001
	Female	50	19.0703	4.56721			
Decision-making	Male	50	16.9541	4.80371	98	3.901	<.001
	Female	50	11.8904	3.60276			

Table 2 shows the significant mean score difference in term of sleep working memory, problem-solving and decision-making. Male reported greater level of working memory, problem-solving and decision-making abilities.

4. Discussion

WM is used to store and evaluate potential solutions or strategies during the problem-solving process. It helps in sequential reasoning and guiding actions toward a solution (Klein et al., 2017). Results of the study depict that working memory positively correlated with problem solving ability and decision making. Male reported greater level of working memory, problem-solving and decision-making abilities. Both problem-solving and decision-making rely on cognitive flexibility and the ability to manage cognitive load. WM's role in cognitive flexibility allows individuals to switch between different problem-solving strategies or adjust decisions based on new information, thereby optimizing outcomes in both domains (Zhang et al., 2014). Effective problem-solving often requires maintaining and manipulating multiple pieces of information, which directly engages WM. The central executive component of WM, responsible for controlling attention and coordinating the activity of other cognitive processes, plays a key role in problem-solving tasks (Baddeley, 2000). Miyake et al. (2000) focused on the role of WM in complex cognitive tasks and found that individual differences in WM capacity were correlated with problem-solving ability. Individuals with higher WM capacity were able to perform better in tasks requiring the integration of multiple pieces of information and the evaluation of potential solutions. Turner & Engle (1989), they examined the relationship between WM and complex reasoning. Their findings indicated that individuals with greater WM capacity could process more information simultaneously, which is crucial for solving complex problems. WM is used to store and evaluate potential solutions or strategies during the problem-solving process. It helps in sequential reasoning and guiding actions toward a solution (Klein et al., 2017). Shamosh & Gray (2008) this study found that individuals with higher WM capacity tend to make more rational decisions. High-WM individuals are better able to consider multiple variables, leading to more accurate judgments and fewer biases. Baddeley et al. (2002) in their study, they explored how WM is linked to decision-making in ambiguous contexts. They concluded that individuals with better WM function were more capable of resolving ambiguity and considering alternative perspectives when making decisions. Research has shown that individuals with better WM are more capable of delaying immediate gratification for a better long-term outcome (Mischel et al., 1989), which is a key feature of sound decision-making. Both problem-solving and decision-making rely on cognitive flexibility and the ability to manage cognitive load. In problem-solving tasks, decision-making plays a critical role in selecting among multiple approaches or solutions. Poor decision-making due to limited WM capacity may lead to suboptimal problem-solving strategies, resulting in inefficiency or failure to find the most effective solution (Gilbert et al., 2005).

5. Conclusion

Working memory is integral in enabling individuals to hold and manipulate information, process alternatives, and make decisions, particularly in complex scenarios. The conclusion underscores the importance of working memory in cognitive flexibility, attention regulation, and decision-making efficiency. Results of the study depict that working memory positively correlated with problem solving ability and decision making. Male reported greater level of working memory, problem-solving and decision-making abilities.

5.1. Contribution of the study

The study of working memory in the context of problem-solving and decision-making in education contributes significantly to understanding how students learn, process information, and arrive at conclusions.

Understanding Cognitive Load: Working memory plays a critical role in managing cognitive load during complex tasks like problem-solving. Studies indicate that students with stronger working memory capacity can handle more information simultaneously, making it easier for them to engage in higher-order cognitive processes such as analysis, reasoning, and evaluation. Educators can use this insight to design more effective lesson plans and learning environments that consider students' cognitive capacities.

Improving Problem-Solving Skills: Working memory enables students to hold and manipulate information in their minds while working through problem-solving tasks. By studying how students use their working memory during problem-solving, educators can identify strategies to help students enhance their ability to break down problems, think critically, and explore multiple solutions. This research also informs the development of teaching techniques that promote the use of strategies like chunking or rehearsal to aid working memory.

Enhancing Decision-Making in Learning Contexts: Decision-making, especially in complex educational tasks, requires the integration of prior knowledge, evaluation of alternatives, and the ability to forecast outcomes. A solid working memory allows students to hold these factors in mind while making decisions about how to approach tasks. Insights from research on working memory help educators understand how students process choices and how best to support them in making informed decisions in their learning journeys.

Individual Differences: Research highlights that working memory capacity differs among students, influencing their learning experiences. Those with limited working memory may struggle with tasks that require holding onto multiple pieces of information at once, while those with greater capacity might excel in more challenging scenarios. This has led to differentiated instructional strategies tailored to students' working memory capacities, ensuring that all learners are supported according to their individual needs.

Interventions for Struggling Students: Studies on working memory provide guidance for developing interventions for students who struggle with working memory deficits. For example, memory aids, scaffolding techniques, and cognitive training programs can be implemented to help these students improve their ability to process and store information, thereby enhancing their problem-solving and decision-making abilities.

Long-term Learning and Transfer: Working memory not only supports current learning but also plays a role in how students transfer knowledge and skills to new contexts. By understanding how working memory interacts with other cognitive processes, educators can create more effective strategies for fostering long-term retention and transfer of skills learned in one situation to new problem-solving and decision-making contexts. In conclusion, research into working memory provides valuable insights into how students engage with complex cognitive tasks. It contributes to developing more effective teaching strategies, identifying areas where students need additional support, and ultimately improving educational outcomes.

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