Faculty of Psychology and Educational Sciences
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CENTRUL DE CERCETARE ȘI EVALUARE PSIHO-PEDAGOGICĂ ȘI SOCIALĂ

BLACK SEA JOURNAL OF PSYCHOLOGY

www.bspsychology.ro

9 772068 464001

BLACKSEA JOURNAL OF PSYCHOLOGY
eISSN: 2068-4649; Print ISSN: 2068-1186

The "Black Sea" Journal of Psychology
Vol. 15, Issue 2, 1-20, Autumn, 2024
ISSN: 2068-4649
www.bspsychology.ro

Exploring cognitive interactions: working memory and conceptual boundaries

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Abstract. The present research aimed to investigate working memory, through two comparisons and a correlation with analytical reasoning. The objectives were to identify differences in working memory levels by age group of participants, identify differences in working memory levels by gender, and identify a statistically significant correlation between working memory and analytical reasoning. The study involved 39 people from Constanta County, thus distributed, 17 women and 22 men in terms of gender. The ages were divided into 2 categories (18-22 and 48-52). The sampling method was of convenience, both tools being applied in the author community, depending on the availability of research participants. These tools used to collect data were: Working Memory Test and Analytical Reasoning Test, provided by Cognitrom. To achieve the objectives, 3 hypotheses were made, 2 of which were confirmed, thus there are significant differences between young and older adults in terms of working memory. Gender has also been shown to be a factor that does not influence working memory. At the same time, it was demonstrated that the existence of a statistically significant positive correlation between the scores obtained in the two questionnaires, working memory and analytical reasoning influencing each other. In conclusion, a clearer picture emerges of the relationship between the two dimensions. The study participants, coming from Constanta County, provided valuable data that contributed to achieving the proposed objectives and evaluating the hypotheses issued.

Keywords: working memory, analytical reasoning

1. Introduction

1.1 Working Memory

Memory, "psychic mechanism for encoding, storing and retrieving information" depends on the individual's past experiences, which are then brought to the surface to be used as needed. Therefore, previous experiences are not lost, they settle, leaving their mark on human life.

In his book, Mielu Zlate refers to the presence of three basic processes of memory, mentioned in many of the definitions given by writers of literature. These processes are memorizing, storing, and updating (Zlate, 1999, p. 345).

Human memory has an "intelligible, mediated and selective" character. Thus, man understands the memorized information, gives it a meaning involving judgment, and then resorts to a series of tools to remember more easily and reproduce the information. Keep in mind that not everything is stored, but only part of the information. This is where subjectivity comes in, the extent to which information is meaningful to the individual (Zlate, 1999, p. 348).

The role of human memory is a very complex one, but also necessary. It ensures stability, continuity, consistency, and finality when it comes to the psychic life of man (Zlate, 1999).

In recent literature there has been considerable confusion about the three types of memory: long-term, short-term, and working memory. Long-term and short-term memory could differ in two fundamental ways, with only short-term memory demonstrating temporal decay and limited storage capacity (Cowan, 2008).

When it comes to cognition, working memory occupies a central role within it. Working memory is involved in a wide variety of cognitive behaviours of great complexity, such as reasoning. problem solving and understanding. Working memory is also responsible for much of the variance in intellectual ability. According to studies in neuropsychology and neuroimaging, working memory is dependent on the structures of the prefrontal cortex (M. Miclea, 2009).

Working memory has been defined in the literature by Baddeley and Hitch as the ability of the cognitive system to store relevant information from the external or internal environment for a short period of time and operate in parallel with it. So, the components of working memory are short-term storage and information processing. Working memory is different from short-term memory, the latter being defined by authors in the literature as a process that temporarily stores information (M. Miclea, 2009).

The mechanisms that are involved in storing and processing information share a unitary volume of cognitive resources. Therefore, the more difficult the processing task, the lower the number of resources allocated to the storage process. The higher the difficulty of one task, the lower the efficiency of the other. We can say that it is in an invert proportional ratio (M.Miclea, 2009).

The best way to study how this cognitive function works is through complex span working memory tasks. Their dual structure respects very well all the constraints faced by the cognitive system, namely the need to keep available and active a series of information for processing, in parallel with the realization of complex processes. Specialists claim that the difference between people with a better working memory and those with a weaker working memory is given by the speed of processing (M. Miclea, 2009).

Working memory has been conceived and defined in three different, slightly discrepant ways: as short-term memory applied to cognitive tasks as a multicomponent system that holds and manipulates information in short-term memory; like using mindfulness to manage short-term memory (Cowan, 2008).

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Working memory has been conceptualized as an active memory system, responsible for temporarily retaining and processing information simultaneously. It has also been defined as the use of temporarily stored information in performing more complex cognitive tasks. Working memory supports cognitive processing by providing a connection between perception, short-term memory, long-term memory, and goal-oriented actions. It is especially necessary for conscious cognitive processing since it allows the internal representation of information to guide decision-making and obvious behaviour. Working memory is one of the main cognitive processes underlying thinking and learning. When it comes to academic learning, working memory capacity is quite limited, even in individuals with normal working memory resources. On average, an individual can only manipulate 4 pieces of information at a time, and these will remain in memory for a short time (Dehn, 2008).

Long-term memory is a vast repository of knowledge and a record of previous events. Short-term memory is believed to reflect the faculties of the human mind that may temporarily hold a limited amount of information in a very accessible state. Working memory is not completely distinct from short-term memory. It is used for planning and performing behaviour (for example, when we make a cake without making the mistake of forgetting and putting an ingredient several times, or when we do mathematical calculations without writing them down on the sheet). In other words, working memory includes short-term memory and other processing mechanisms that help utilize short-term memory (Cowan, 2008).

1.2 Capacities and limits of memory

One of the first problems encountered in trying to determine whether short-term memory functions as a working memory was the fact that there was no agreement on the characteristics of short-term memory. If we were to take all the existing models of short-term memory and then test them one by one, this would have been a long time coming. Fortunately, there were two characteristics on which all models agreed, namely that short-term memory has limited storage capacity and that, in terms of verbal memory capacity, for example, the maximum length of the string of digits corresponding to a telephone number, which can be reproduced, relies heavily on short-term memory (Neacsu, 1990).

Working memory systems hold their own resources and some autonomy in terms of operation. Working memory allows the subject to use information in a motor reaction or transfer it to long-term memory (MLD). Working memory is more than a more elaborate version of short-term memory, thus substantiating a new concept (Zlate, 1999).

1.3 The central executive system

Baddeley and Hitch identified three components of working memory, with the central executive component being the most important. Its functions include regulating the flow of information in working memory, retrieving information from other memory systems, but also processing and storing information. The processing resources, which the central executive uses to perform various functions, have limited capacity. The efficiency of the executive component is reduced when other demands are placed on it simultaneously. The composition of the central executive is complemented by two other components called "slave systems". Each system specializes in processing and temporary storage of material (A.D. Baddeley, 1993).

The central executive component of working memory controls the phonological bubble and representation system through diagrams, linking them with long-term memory. The executive system is almost certainly much more complex than either of the two subordinate

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systems, and because of this, it is much harder to research. One of the attempts to approach working memory, which was advanced in parallel with this model, sought to define working memory starting from the need to combine memory and processing. Actions that rely on this function are developed and used to measure the working memory capacity of groups of subjects. Differences in capacity between subjects can be correlated in this case with differences in the execution of complex actions, such as the ability to understand and solve problems. This approach has been a considerable success in exploring the process of language comprehension (Baddeley, 1999).

Patrick Kyllonen, who works in the U.S. Air Force, explored the possibility of using working memory capacity assessments as an alternative to traditional, reasoning-based assessments of intelligence. The issue has interested the U.S. Air Force because it must recruit individuals from different backgrounds who have not received the same training, and training is a factor that can exert a major effect on many standard tests for intelligence. Using a series of actions involving working memory, Kyllonen found that working memory performance was highly correlated with reasoning possibilities. The main difference between these two parameters was that assessments of working memory were to a greater extent dependent on the speed of information processing, while actions involving reasoning depended more on prior knowledge. In further experience, subjects were assessed for working memory and reasoning ability, then asked to undergo a two-week computer programming training course. Although estimates of working memory and reasoning ability were strongly correlated, working memory proved to be a better predictor of programming success than standard academic measures. A similar result was obtained in another study in which subjects were asked to learn about logical ratio. Consequently, although our knowledge of the central executive system is very limited, the concept of working memory is already proving to be worthy of interest (Zlate, 1979).

1.4 The phonological loop system

We recall that one of the characteristics frequently attributed to short-term memory is that it rests on verbal encoding, most short-term memory models involve a process of repeated practice, usually through mental verbalization, to fix information. The phonological loop is a subordinate system, with a role in storing and processing verbally encoded information. The existence of such a subordinate system is supported by three categories. The first of these corresponds to the effect of phonological similarity of the mis-reproduced term with the correct term or due to a succession of elements having a similar verbal expression and which are extremely difficult to recall in the order presented (Zlate, 1996).

A second category is based on the observation that immediate updating of visually presented figures may be possible when one is asked to ignore irrelevant material presented verbally. Updating is possible to the same extent regardless of the language of presentation of the verbal material, which suggests that the process of updating operates more at the level of sound than meaning of words (Faur, 2002).

A third source of information on the phonological loop came from other experiments conducted on the relationships between word length and retention. The activity in which mental repetition is supposed to play an important role is reading. Man usually "hears" what he reads, as if speaking of an inner voice, which could be attributed to the articulatory loop. Thus, the articulatory loop seems to act as a particularly effective verification mechanism in terms of preserving the order of an information sequence (Buzan, 1971).

1.5 Memory and age

When we refer to memory, we don't think of something finite or static. We can talk about an internal dynamic, but also about a dynamic in time, in the sense that memory has a progressive evolution, with an ascending character, from lower to higher. Therefore, memory evolves with human age (Zlate, 1999).

The literature indicates that the efficiency of working memory varies significantly at different stages of development. For the first part of life, the differences are significant, each stage being dominated by major changes in the ability to retain and process information. But for this research we will focus on the differences that occur between two age groups: younger people (under 30) and older adults (over 40).

1.6 Working memory in young adults (under 30)

Young adults, under the age of 30, are often at the peak of cognitive performance. This stage of life is characterized by high capacity and efficiency of working memory. According to Gathercole et al. (2004), working memory improves significantly during childhood and adolescence, reaching its full potential around age 20. This peak is marked by the ability to simultaneously manage multiple pieces of information and perform complex cognitive tasks with relative ease.

Neuroscientific studies have shown that the prefrontal cortex, a brain region heavily involved in encoding, updating, and preserving internal representations in working memory, fully develops around age 25 (Sowell et al., 2003). This development allows for better integration of sensory input and more efficient execution of executive functions such as attention control and problem solving. Consequently, young adults demonstrate superior performance in tasks that require quick thinking, multitasking, and adaptive learning.

1.7 Working memory in older adults (over 40)

In contrast, people over 40 often experience a decrease in working memory capacity and efficiency. This decrease is part of the broader cognitive aging process. Research by Park and Reuter-Lorenz (2009) indicates that working memory, along with other executive functions, begins to deteriorate as early as age 35, with more noticeable deficits occurring after age 40. This deterioration can be prevented by training memory, of course.

Structural and functional changes in the brain also contribute. For example, the prefrontal cortex and hippocampus, crucial areas for working memory, exhibit age-related atrophy (Raz et al., 2005). In addition, there is a reduction in the availability of dopamine, a neurotransmitter essential for cognitive processes, which affects the efficiency of neural networks involved in memory and operating tasks (Bäckman et al., 2006).

Older adults often compensate for these decreases based on accumulated knowledge and experience; a phenomenon known as "cognitive reserve" (Stern, 2002). While it may mitigate some of the effects of working memory decline, it does not entirely counteract age-related cognitive decline. The practical implications of this decline include difficulties in multitasking, slower information processing speeds, and difficulty adapting to new information or tasks.

Comparing the working memory performance of young and older adults highlights the dynamic nature of cognitive abilities throughout life. While young adults' benefit from optimal brain function and high cognitive flexibility, older adults must deal with structural changes in the brain that reduce working memory capacity. However, the extensive experience and cognitive strategies developed by older adults can partially compensate for these decreases, allowing them to perform effectively in tasks that are familiar or based on long-term knowledge.

This comparative understanding has practical implications, particularly in the design of educational programmes, on-the-job training and cognitive interventions tailored to different age groups. For younger people, strategies that harness their cutting-edge cognitive abilities and adaptability are effective. In contrast, for older adults, approaches that leverage their experience and provide support for declining working memory functions can improve cognitive performance and quality of life.

1.8 Analytical reasoning

Analytical reasoning in psychology is an essential process of human cognition in which individuals break down complex information into smaller, more understandable components to better process it, draw conclusions, and make decisions. This type of reasoning involves skills such as critical analysis, synthesis of information, and logical evaluation of data and arguments.

Analytic reasoning describes a critical thinking skill that uses logic to answer complex questions. By identifying patterns in facts or rules, one can use those patterns to determine which results can or should be true.

Over time, many psychologists have brought up analytical reasoning and its problems. Thus, Wilhelm Wundt, often considered the "father of modern psychology", established the first psychology laboratory in Leipzig, Germany, in 1879. He pioneered the approach to structuralism, which aimed to analyse consciousness in its basic elements. Wundt used analytical methods, such as introspection, to break down mental experiences into their constituent parts (Blumenthal, A. L., 1980).

Behaviourism, which emerged at the beginning of the twentieth century, emphasized the study of observable behaviour and rejected the use of introspection and subjective experiences. Psychologists such as John B. Watson and B.F. Skinner used experimental analysis to investigate the relationship between stimuli and responses, laying the foundation for a more rigorous and analytical approach to the study of behaviour (Skinner, B. F., 1984).

Freudian psychoanalysis and analysis: the psychoanalytic theory of Sigmund Freud introduced a new dimension in psychological analysis, focusing on unconscious processes and motivations. Freud used analytical techniques such as free association and dream analysis to discover hidden conflicts and psychological phenomena, contributing to the development of deep psychology.

This science of analytical reasoning provides the reasoning framework upon which both strategic and tactical visual analysis technologies for threat analysis, prevention, and response can be built. Analytic reasoning is central to the analyst's task of applying human judgments to reach conclusions from a combination of evidence and assumptions (Ribarsky, W., et al, 2009).

Analytical reasoning serves several important purposes in various fields, including academia, science, business, law, and day-to-day decision making. Here are some key uses of analytical reasoning:

- Problem solving
- Critical thinking
- Decision making
- Research and investigation
- Strategic planning
- Problem identification
- Argumentation and persuasion
- Interpretation and understanding

Overall, analytical reasoning is a versatile and valuable cognitive skill that empowers individuals to think critically, solve problems, make decisions, and navigate the complexities of the world around them. It is an essential tool for success in both personal and professional life (Cullen, S., et al, 2018). Analytical reasoning is essential in various fields, from academic and professional environments to day-to-day decision making. It underpins scientific research, mathematical problem solving, legal reasoning and strategic planning. In education, developing analytical reasoning skills is crucial for preparing students to tackle complex problems and make informed decisions.

In the work environment, people with strong analytical reasoning skills are better equipped to analyse data, solve problems, and develop innovative solutions. Thus, organizations often prioritize these skills in hiring and professional development programs.

Visual analysis strives to facilitate the process of analytical reasoning by creating software that maximizes human ability to perceive, understand, and reason complex and dynamic data and situations. It must be based on an understanding of the reasoning process, as well as an understanding of the underlying cognitive and perceptual principles, to provide mission-appropriate interactions that allow analysts to have true discourse with their information. The goal is to facilitate high-quality human reasoning with a limited investment of analysts' time (Schwarz, N., & Bless, H., 2020).

In emergency management and border security contexts, analytical reasoning provides the basis for multi-layered data extraction to convey the right information at the right time and place. It provides principles for conveying context-appropriate information that can be cascaded across an organization to support rapid decision-making.

Understanding the logical structure of arguments is the foundation for advanced reasoning and academic work. However, while one of the basic objectives of higher education is to prepare students to fully understand and reason argumentative texts, the preconditional ability to analyse such texts in their logical components is rarely taught explicitly in universities. Moreover, a standard university education produces only modest improvements in students' analytical reasoning skills. Because many students enter college without well-developed analytical skills, the benefits they derive from their readings and courses are limited (Eagan, MK, et al., 2014).

Analytical reasoning develops throughout life, influenced by both cognitive maturation and environmental factors. In early childhood, reasoning skills are rudimentary and mainly concrete. Piaget (1952) observed in children in the preoperational stage (2-7 years) that they have difficulty thinking logically and are mainly egocentric. As children move to the stage of concrete operations (7-11 years), they begin to understand logical operations, although their reasoning remains related to concrete objects and experiences.

In adolescence, generally from 12 to 18 years, individuals enter Piaget's stage of formal operations, where they develop the ability to think abstractly and hypothetically. This stage marks a significant improvement in analytical reasoning skills, enabling adolescents to manage complex problems and engage in systematic planning.

Analytical reasoning continues to evolve into adulthood but may differ between young and older adults. Research indicates that peak performance in tasks requiring fluid intelligence, which underpins analytical reasoning, occurs around age 30 (Horn & Cattell, 1967). Fluid intelligence involves the ability to solve new problems and think abstractly, both essential for analytical reasoning.

People under 30 tend to do better in tasks that require fast processing and flexible thinking. However, as people age, they often experience a decline in fluid intelligence, but maintain or even improve their crystallized intelligence, which involves accumulated knowledge and experience (Horn, 1982). This shift suggests that although older adults may process information more slowly, their vast knowledge base may compensate for this decline in certain contexts.

Analytical reasoning skills have also been studied by gender, with some differences observed. Studies generally indicate that although men and women may approach problems differently, there is no consistent evidence of an overall significant difference in analytical reasoning skills. Halpern (2012) found that men often excel in spatial reasoning tasks, which can be a component of analytical reasoning, while women tend to do better in verbal reasoning tasks.

Performance differences are often attributed to social and cultural factors rather than inherent cognitive abilities. Educational experiences, societal expectations, and opportunities to engage in different types of reasoning tasks play a crucial role in shaping these skills across genders.

In conclusion, analytical reasoning is a critical cognitive skill that develops throughout life, influenced by cognitive maturation, educational experiences, and environmental factors. While young adults excel at tasks that require quick and flexible thinking, older adults leverage their vast knowledge base to maintain a high level of performance in analytical reasoning tasks. Gender differences in analytical reasoning are largely shaped by social and cultural influences rather than inherent cognition. Understanding and developing analytical reasoning skills are essential for personal and professional success in an increasingly complex world.

2. Research Methodology

2.1. Objectives and Hypotheses

Research Objectives:

1. Identify differences in the level of working memory according to the age category of participants.
2. Identify differences in working memory levels depending on the gender of participants.
3. Identify the existence of a statistically significant correlation between the level of working memory and analytical reasoning.

Research Hypotheses:

1. It is assumed that there are statistically significant differences in the level of working memory depending on the age group of participants.
2. It is assumed that there are statistically significant differences in the level of working memory depending on the gender of the participants.
3. It is assumed that there is a positive, statistically significant correlation between the level of working memory and the level of analytical reasoning.

2.2. Research sample

The sample consists of 39 participants from Constanta County, thus distributed, 17 women and 22 men in terms of gender. The ages were divided into two categories, with 20 participants aged 18 to 22 and 19 participants aged 48 to 52.

2.3. Instrumentation description

To conduct this research, we used 2 different tools to measure working memory and the level of analytical reasoning:

2.3.1. The working memory tests

The working memory test is provided by the Cognitrom team (COGNITROM ASSESSMENT SYSTEM) to evaluate the capacity of simultaneous storage and processing of information, implicitly to measure the working memory of the test subjects. This test can be applied to a population between the ages of 12 and 67. In the case of our research, the administration of this test was done without time limit, using the pencil-paper technique. The type of task used in testing was the "series of numbers and letters" paradigm. This paradigm, developed by J. Gold and his collaborators, implies a simultaneous unfolding of all mechanisms of information storage and processing. The test involves the presentation of strings of letters and numbers. The tester reads the strings aloud, and the test subject has the task of listening carefully to the order in which they were read, memorizing them, and ordering first the digits ascending (1-9) and then the letters alphabetically (A-O). After that, the test subject says them out loud in the correct order, and the examiner notes. These strings increase progressively from one series to another, changing the degree of difficulty (Miclea, 2009).

The working memory test consists of 7 series of 5 strings each containing combinations of numbers and letters. So, it contains 35 items. Each string is made up of several varying digits (from 1 to 9) and letters (from A to O). As far as quotation is concerned, only strings that have been updated entirely correctly will be scored. For each series (I-VII), divide the number of elements that are part of that string by the number of strings in the series (always 5). Thus, the score for each series will be obtained (Miclea, 2009).

2.3.2. The Analytical Reasoning Test

The Analytical Reasoning Test is designed to assess an individual's ability to discover rules and use them to solve reasoning problems. It targets two types of reasoning: inductive and deductive, being structured in two subscales corresponding to each of these types. Inductive reasoning involves the production of general knowledge based on data, and the related subscale includes items organized into sets of geometric figures or letters, participants having to identify and generalize the rules of their formation. Deductive reasoning consists in making calculations governed by rules of deduction, the corresponding subscale including items that present premises in the form of situations and requires the identification of the logical conclusion arising from these premises.

The test can be administered to people aged between 12 and 67 years of the normal population, individually or collectively, in pencil-paper form or in computer program, with a time limit of 14 minutes in total. The test does not require knowledge specific to a particular field, making it suitable for assessing reasoning skills in various professional contexts and beyond.

2.4. Verification of hypothesis and statistical interpretation of data

Hypothesis 1. It is assumed that there are statistically significant differences in the level of working memory depending on the age group of participants.

Table 1.1.- Descriptive statistics (age category of participants)

Descriptive

	Participant's age			Statistic	Std. Error
Working memory score	48-52	Mean		14,063	1,5449
		95% Confidence Interval for Mean	Lower Bound	10,817	
			Upper Bound	17,309	
		5% Trimmed Mean		13,409	
		Median		11,500	
		Variance		45,348	
		Std. Deviation		6,7341	
		Minimum		5,9	
		Maximum		34,0	
		Range		28,1	
		Interquartile Range		8,2	
		Skewness		1,560	,524
		Kurtosis		3,062	1,014
	18-22	Mean		23,200	1,9873
		95% Confidence Interval for Mean	Lower Bound	19,040	
			Upper Bound	27,360	
		5% Trimmed Mean		23,161	
		Median		24,350	
		Variance		78,989	
		Std. Deviation		8,8876	
		Minimum		7,1	
		Maximum		40,0	
		Range		32,9	
		Interquartile Range		12,3	

BLACKSEA JOURNAL OF PSYCHOLOGY
eISSN: 2068-4649; Print ISSN: 2068-1186

The "Black Sea" Journal of Psychology
Vol. 15, Issue 2, 1-20, Autumn, 2024
ISSN: 2068-4649
www.bspsychology.ro

	Skewness	,171	,512
	Kurtosis	-,543	,992

Table 1.2- Test of normality (Kolmogorov-Smirnov) for working memory score by age

Tests of Normality

	Participant's age	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Working memory score	48-52	,175	19	,130	,867	19	,013
	18-22	,098	20	,200*	,976	20	,874

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

According to the Kolmogorov-Smirnov normality test, we obtained a normal distribution in the 48-59 age category and in the 18-22 age category (Sig. >0.05). Thus, further we will apply a parametric test.

Table 1.3.- Parametric T Test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Working memory score	Equal variances assumed	1,736	,196	-3,604	37	,001	-9,1368	2,5352	-14,2736	-4,0001
	Equal variances not assumed			-3,630	35,296	,001	-9,1368	2,5172	-14,2455	-4,0282

The "Black Sea" Journal of Psychology
Vol. 15, Issue 2, 1-20, Autumn, 2024
ISSN: 2068-4649
www.bspsychology.ro

According to the parametric T-test, Sig. (2-tailed) has a value of 0.01 and is lower than 0.05, which indicates that there are significant differences between the 2 samples in terms of the score obtained on the working memory test.

There are statistically significant differences, with people in the 18-22 age group having higher scores than subjects in the 48-59 age group. The hypothesis is confirmed!

2.4.1. Psychological interpretation of the results

According to statistical results, there are significant differences depending on the age of the participants, regarding the quality of working memory. Thus, younger people scored higher than older people.

A decrease in working memory capacity is expected with increasing age Such a decline has been demonstrated with different paradigms: delayed recognition load or so-called n-back task, in which a stimulus currently presented should be compared with stimuli previously presented (Nyberg et al., 2009; Schmiedek).

An age-related degradation of the neural substrate is pronounced in the frontal lobe (West, 1996; Raz et al., 1998) and may be related to decreased working memory performance. However, the mechanisms of age-related declines in working memory performance are not yet fully understood. A widely accepted age-related hypothesis is a deficit in filtering or suppressing irrelevant information which, in turn, can strain limited working memory capacity and reduce performance (Hasher and Zacks, 1988; Gazzaley et al., 2005).

The present study, "Age-related differences in working memory performance in a 2-back task", aims to elucidate the neurocognitive processes underlying age-related differences in working memory. Young and middle-aged participants performed a two-way task: a low-level task and a continuous working memory performance (2-back) task. The P300 coefficient and underlying neural sources of expected age-related differences were analysed using sLORETA. The response speed was generally slower for the middle-aged group than for the younger group. Analysis of the source revealed greater activation for the youth group versus the middle-aged group in areas of the brain that support working memory processes. (Wild-Wall, 2011)

Working memory and episodic memory decline with age. This was developed in the study "A comparison of visual working memory and episodic memory performance in younger and older adults ". A task design was developed in which visual working memory and episodic memory performance were measured using the same stimuli. A continuous performance (2-back) working memory load was followed by a subsequent recognition memory task. The study compared the performance of younger adults and older adults. Older adults performed worse than younger adults with no interaction effect. In younger adults, but not in older adults, performance on the two tasks was concurrent. We conclude that the relationship between the two memory systems differs depending on the age group (Lugtmeijer, 2019).

Hypothesis 2. It is assumed that there are statistically significant differences in the level of working memory, depending on the gender of the participants.

BLACKSEA JOURNAL OF PSYCHOLOGY
eISSN: 2068-4649; Print ISSN: 2068-1186

The "Black Sea" Journal of Psychology
Vol. 15, Issue 2, 1-20, Autumn, 2024
ISSN: 2068-4649
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Table 2.1.- Descriptive statistics (gender)

Descriptive

	Participant's gender			Statistic	Std. Error
Working memory score	masculine	Mean		16,082	1,6758
		95% Confidence Interval for Mean	Lower Bound	12,597	
			Upper Bound	19,567	
		5% Trimmed Mean		15,438	
		Median		14,250	
		Variance		61,783	
		Std. Deviation		7,8602	
		Minimum		7,1	
		Maximum		37,4	
		Range		30,3	
		Interquartile Range		9,8	
		Skewness		1,218	,491
		Kurtosis		1,162	,953
	feminine	Mean		22,200	2,3280
		95% Confidence Interval for Mean	Lower Bound	17,265	
			Upper Bound	27,135	
		5% Trimmed Mean		22,117	
		Median		21,700	
		Variance		92,130	
		Std. Deviation		9,5984	
		Minimum		5,9	
		Maximum		40,0	
		Range		34,1	
		Interquartile Range		15,1	

	Skewness	,132	,550
	Kurtosis	-,607	1,063

Table 2.2- Test of normality (Kolmogorov-Smirnov) for working memory score by gender

Tests of Normality

	Participant's gender	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Working memory score	masculine	,201	22	,021	,887	22	,017
	feminine	,111	17	,200*	,968	17	,788

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

According to the Kolmogorov-Smirnov normality test, we obtained a normal distribution for female respondents (Sig.>0.05) and a non-normal distribution for male respondents' scores. Thus, further we will apply a nonparametric test.

Table 2.3.- Mann-Whitney U Test

Test Statistics

	Working memory score
Mann-Whitney U	118,000
Wilcoxon W	371,000
Z	-1,954
Asymp. Sig. (2-tailed)	,051
Exact Sig. [2*(1-tailed Sig.)]	,052[b]

a. Grouping Variable: Participant's gender

According to the nonparametric Mann-Whitney U test, Asymp Sig. has a value of 0.51 and is greater than 0.05, which indicates that there are no significant differences between the 2 samples in terms of working memory. **The hypothesis does not confirm!**

2.4.2. Psychological interpretation of results

According to the statistical results, there are no significant differences in working memory according to the gender of the participants.

Research shows that individual variability in working memory performance is much greater than differences between genders. In a mixed group of women and men, individual differences in working memory capacity are considerably more pronounced than any average difference between genders. This indicates that gender is not a significant predictor of performance in working memory tasks.

Several meta-analyses, combining results from numerous individual studies, have shown that gender differences in working memory are either non-existent or very small. For example, a meta-analysis by Lachman and colleagues in 2014 concluded that gender differences in working memory performance are negligible and statistically insignificant. This suggests that, in general, women and men have similar working memory capacities (Lachman, M. E., et al., 2014).

Another relevant meta-analysis supporting the argument that there are no significant differences between women and men in working memory is conducted by Lynn and Irwing in 2016. This meta-analysis examined many studies to assess gender differences in various cognitive abilities, including working memory.

Lynn and Hur Y. analysed 57 studies that investigated gender differences in working memory and found that the average effects were very small, close to zero. This indicates that, overall, men and women show no significant differences in working memory performance (Lynn, R., & Hur, Y. M., 2016).

In contexts where women and men benefit from the same educational and cognitive development opportunities, their performance in working memory tasks is very similar. This highlights the fact that differences observed in the past may be the result of socio-cultural influences rather than biological differences. Studies show that the effects of gender stereotypes can influence cognitive performance. When these stereotypes are neutralized, gender differences in working memory performance tend to disappear, suggesting that many previously observed differences can be attributed to social pressures and cultural expectations.

Individual studies have produced inconsistent results on gender differences in working memory, with some reporting advantages for men, others for women, and many finding no significant difference at all. This variability indicates that there is no clear consensus to support the existence of significant gender differences. Based on these arguments, gender differences in working memory are essentially negligible. Individual and contextual factors, as well as sociocultural influences, play a much more significant role in determining performance in working memory tasks than gender. Therefore, both women and men have similar working memory capacities, and any differences observed are most likely due to variables other than gender itself.

Hypothesis 3. *It is assumed that there is a positive, statistically significant correlation between the level of working memory and the level of analytical reasoning.*

BLACKSEA JOURNAL OF PSYCHOLOGY
eISSN: 2068-4649; Print ISSN: 2068-1186

The "Black Sea" Journal of Psychology
Vol. 15, Issue 2, 1-20, Autumn, 2024
ISSN: 2068-4649
www.bspsychology.ro

Table 3.1 – Descriptive statistics *for working memory score and analytic reasoning score.*

Descriptive

			Statistic	Std. Error
Working memory score	Mean		18,749	1,4534
	95% Confidence Interval for Mean	Lower Bound	15,806	
		Upper Bound	21,691	
	5% Trimmed Mean		18,320	
	Median		17,300	
	Variance		82,381	
	Std. Deviation		9,0764	
	Minimum		5,9	
	Maximum		40,0	
	Range		34,1	
	Interquartile Range		13,5	
	Skewness		,672	,378
	Kurtosis		-,390	,741
Working memory score	Mean		13,95	,800
	95% Confidence Interval for Mean	Lower Bound	12,33	
		Upper Bound	15,57	
	5% Trimmed Mean		14,08	
	Median		14,00	
	Variance		24,945	
	Std. Deviation		4,994	
	Minimum		4	
	Maximum		22	
	Range		18	

Interquartile Range	7	
Skewness	-,377	,378
Kurtosis	-,872	,741

Next, to verify the hypothesis, the Kolmogorov-Smirnov Test was applied, and histograms were drawn for both scores. From the Normality Test (Table 3.2), it appears that the distribution for working memory is normal, while the distribution of scores of participants in the analytical reasoning test does not comply with normality, so a nonparametric method was applied.

Table 3.2 - Normality test for working memory score and analytic reasoning score

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Working memory score	,123	39	,141	,939	39	,035
Analytic reasoning score	,147	39	,034	,952	39	,098

a. Lilliefors Significance Correction

Table 3.3. – Spearman Test

Correlations

			Working memory score	Analytic reasoning score
Spearman's rho	Working memory score	Correlation Coefficient	1,000	,455**
		Sig. (2-tailed)	.	,004
		N	39	39
	Analytic reasoning score	Correlation Coefficient	,455**	1,000
		Sig. (2-tailed)	,004	.
		N	39	39

**. Correlation is significant at the 0.01 level (2-tailed).

Looking at Table 3.3, we can see that there is a statistically significant correlation between the two variables, where Sig. (2-tailed) =0.004 < 0.05. Also, the correlation coefficient is 0.455, which indicates a moderate correlation between the two scores. Fig. 3.3 shows the correlation graph, with the point cloud pointing to the upper right corner. A positive correlation indicates that when one variable increases, so will the other. Therefore, we can say that the hypothesis issued is confirmed, a high level of working memory also suggesting a high score of analytical reasoning.

2.4.3. Psychological interpretation of results

The result obtained is supported by specialized literature, studies in the field demonstrating that there is a significant correlation between working memory and analytical reasoning. Research by Kane and Engle (2002) explores the relationship between working memory capacity and various aspects of cognitive performance, including analytical reasoning. This study shows that working memory, influenced by the functioning of the prefrontal cortex, is essential for maintaining and manipulating information necessary in analytical reasoning processes. It stands out that people with greater working memory capacity tend to perform better in analytical reasoning tasks, since they can manage complex information more efficiently and use it to generate innovative and logical solutions to the problems encountered.

Research by Süß and colleagues (2002) also investigates how working memory capacity is related to reasoning skills. The results suggest that much of the individual differences in reasoning skills, including analytical reasoning, can be attributed to variations in working memory capacity. The study highlights that people with a more developed working memory are better able to process and manipulate information necessary for deductive and inductive reasoning. This is because working memory allows several relevant information to be maintained simultaneously, thus facilitating the discovery and application of logical rules to solve complex problems.

Another relevant study is the one conducted by Oberauer et al. (2003), which investigated the role of proactive interference in working memory and analytical reasoning. Their results suggest that people with greater working memory capacity are less susceptible to interference and thus can maintain and process relevant information more efficiently, improving performance in analytical reasoning. This indicates that not only the amount of information a person can retain is important, but also the ability to manage interference and distractions.

In conclusion, the correlation between working memory and analytical reasoning is well documented and complex, involving both information storage capacity and executive control and interference management processes. Multiple studies highlight the importance of these components in understanding how working memory influences analytical reasoning and cognitive performance in general.

3. Conclusions

During this research, we studied some of the variables that can be differentiated in the case of working memory, as well as the correlation between this and analytical reasoning.

We can say that the objectives of the study have been achieved, and that almost all hypotheses have been confirmed.

For the first hypothesis (It is assumed that there are statistically significant differences in the level of working memory, depending on the age group of participants.) we used a parametric method to find out if there were significant differences between samples. This assumption was confirmed, with significant differences between the sample aged 18 to 22 years and those aged 48 to 52 years. Both the literature and the studies found attest to the confirmation of this hypothesis.

For the second hypothesis (It is assumed that there are statistically significant differences in the level of working memory, depending on the gender of the participants.) we used a nonparametric method. The hypothesis was disproved, the results indicating insignificant differences between the two samples. Studies support

The third hypothesis of the research (It is assumed that there is a positive, statistically significant correlation between the level of working memory and the level of analytical reasoning.) was also verified by a nonparametric test. The hypothesis has been confirmed, indicating the existence of a statistically significant correlation. Studies that have been conducted on this topic support the existence of this correlation,

The challenge of the research was to equalize the samples as appropriately as possible, according to gender and age category, and a perfect equalization could not be possible. However, participants were responsive.

The ethical norms and conditions were respected, and the application of the tools was optimal, the participants being timed to accomplish each task. This made it possible to process data in the statistical program "SPSS" to generate results for the purpose of verifying hypothesis.

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