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Factors Affecting Working Memory Capacity: a Meta-Analysis Study

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Abstract: Working memory capacity (WMC) is a brain memory system that has a limited ability to process and store temporary information. The purpose of this study was to find out in more detail the factors affecting working memory capacity. The research method uses Meta-analysis quantitatively by combining several research results using Jeffreys's Amazing Statistics Program (JASP) software. The size of the effect used is the odds ratio. Research search using Prisma strategy by searching journal articles from various databases including Scopus, Proquest, Science Direct, CINAHL, and Google Scholar in the last five years from 2019 to 2023. Results Variation between variables is heterogeneous, so this meta-analysis uses a random-effect model, obtained results there is an influence between age on working memory capacity with a combined effect of OR= 3.15 (95% CI 2.10; 4.20), there is an effect of sleep quality on working memory capacity with a combined effect of OR= 6.45 (95% CI 3.51; 9.39), there is an effect of physical activity on working memory capacity with a combined effect of OR=2.84 (1.98; 3.11), there was an effect of listening to music on working memory capacity with a combined effect of OR=3.24 (2.65; 5.13). In conclusion, age, sleep quality, physical activity, and music are factors that affect working memory capacity.

Keywords: Age; Capacity; Factors affecting; Music; Physical activity; Sleep quality; Working memory

Introduction

Working memory is an important component of system memory. Working memory has a capacity called working memory capacity. Working memory capacity is the brain's ability to temporarily store information for a short time and process it actively. Working memory capacity can affect a person's ability to plan, process information, and solve problems (Du et al., 2022; Musa et al., 2023; Xu et al., 2022).

A person's working memory capacity can vary between individuals because it is influenced by various factors. Some studies say that age, sleep quality, and physical activity can affect working memory capacity (Bartsch et al., 2019; Kavanagh & Hourihan, 2020; Tse et al., 2019; van Beers et al., 2021). Some research also suggests that working memory capacity can be affected by environmental factors, such as music listening habits (Mussoi, 2021; Ribeiro et al., 2022; Sukmawati et al., 2023).

Working memory capacity problems can have an impact on a person's ability to process information and make decisions. In everyday life, working memory capacity is essential in completing tasks that require information processing in a short time (Burgoyne et al., 2019; Felez-Nobrega et al., 2018). A person with memory impairment can also cause sufferers to have difficulty storing, controlling, and recalling memories. In children with below-average working memory capacity, they tend to experience difficulties and constraints in academics (Aubry et al., 2021; Nagaraj et al., 2020; Rachmad et al., 2023).

Increased working memory capacity can help improve a person's performance in a variety of tasks, including academic tasks (Asp et al., 2021; Pedale et al., 2023). Research on working memory capacity is important for understanding how the human brain works and how it can improve working memory capabilities. Therefore, it is necessary to know the factors that affect working memory capacity.

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Method

This research uses a quantitative meta-analysis study method by combining several research results using Jeffreys's Amazing Statistics Program (JASP) software. The size of the effect used is the odds ratio. Research search using PRISMA strategy by searching journal articles from various databases including Scopus, Proquest, Science Direct, CINAHL, and Google Scholar in the last five years from 2019 to 2023.

Result and Discussion

The results of PRISMA found 473 articles identified through the five databases contained in research methods and screened through titles. Full-text articles that have been reviewed for eligibility are obtained totaling 70 articles.

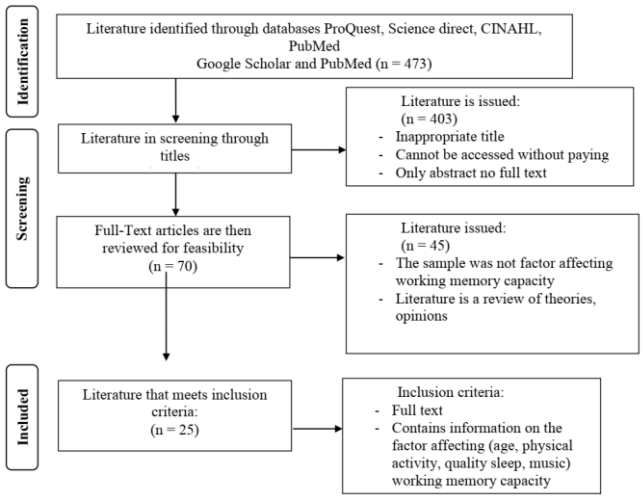

Figure 1. Literature flowchart for meta-analysis

Table 1. Influencing Factor Values (Source: author-processed data output, 2023)

Research Variables	(n) Study	Random-effect model (OR 95% CI)	z	ρ-value
Age	5	3.15 (2.10; 4.20)	5.88	< 0.001
Sleep quality	7	6.45 (3.51; 9.39)	4.30	< 0.001
Physical activity	7	2.84 (1.98; 3.11)	3.76	0.002
Listen to music	6	3.24 (2.65; 5.13)	6.17	< 0.001
	Total n = 25			

Table 2. Publication Bias (Source: author-processed data output, 2023)

Research Variables	(n) Study	Rank correlation test		Regression test	ρ-value
			Kendall's τ	ρ-value	z
Age	5	0.59	0.283	1.39	0.16
Sleep quality	7	0.50	0.177	1.75	0.45
Physical activity	7	-0.14	0.376	-0.39	0.31
Listen to music	6	0.21	0.231	1.85	0.22
	Total n = 25				

Age Factors Affect the Working Memory Capacity

The value of the Factor affecting the age variable can be seen in Table 1 that the random effect model value has an effect size value of 3.15 with a z value of 5.88. The result of the value of ρ-value is compared with the value of α = 0.05, if ρ ≥ α. Based on the table above, ρ < 0.001. The value is smaller than α (0.05) which means there is an influence between age and working memory capacity. An estimated value of 3.15 (95% CI 2.10; 4.20) indicates that older age factors can affect the decline in working memory capacity 3.15 times than younger age.

A publication bias test is conducted to see whether the data used in the meta-analysis can be used as a representative sample of the population. Table 2 shows the values of rank correlation and regression method. Kendall's τ value in the rank correlation test column is the magnitude of the correlation coefficient between effect size and variance which is 0.59 and the z value in the regression test column is the magnitude of the regression coefficient which is 1.39. The value of ρ is compared to the value of α, if ρ-value ≥ α = 0.05, then the null hypothesis (funnel plot symmetry) which means it is not indicated publication bias. The value of ρ in the rank correlation test column of 0.283 is greater than α (0.05) indicating no publication bias in the age variable.

Sleep Quality Factors Affect the Working Memory Capacity

The value of the influencing factor in the sleep quality variable can be seen in the random effect model value in Table 1 that the effect size value is 6.45 with a z value of 4.30. The value of ρ-value <0.001 which means less than α (0.05) then the hypothesis is accepted, which means that sleep quality affects working memory capacity. An estimated value of 6.45 (95% CI 3.51; 9.39) showed that poor sleep quality decreased working memory capacity 6.45-fold in people with good sleep quality.

A publication bias test is conducted to determine

whether the data used in the meta-analysis can be used as a representative sample of the population. Table 2 shows the values of rank correlation and regression method. Kendall's τ value in the rank correlation test column is the magnitude of the correlation coefficient between effect size and variance, which is 0.56 and the z value in the regression test column is the magnitude of the regression coefficient, which is 1.75. The value of ρ is compared to the value of α, if ρ-value ≥ α = 0.05, then the null hypothesis (funnel plot symmetry) which means it is not indicated publication bias. The value of ρ in the rank correlation test column of 0.177 is greater than α (0.05) indicates no publication bias in the sleep quality variable.

Physical Activity Factors Affect the Working Memory Capacity

The z value in Table 1 shows a score of 3.76, while the ρ-value is 0.002 which means less than the significance value of 5% (0.05). This means that H0 is rejected, in other words, true effect size is not equal to (#) zero (0). This means that physical activity variables have a significant influence on working memory capacity. An estimated value of 2.84 (95% CI 1.98; 3.11) showed that less physical activity decreased working memory capacity 2.84-fold than people who had good physical activity.

The ρ-value in Table 2 is 0.376 > 0.05 which indicates that H_0 is rejected, which means there is no indication of publication bias. Kendall's τ value of -0.14 indicates that many and large samples were not included in the sample of this study, more dominant samples with little or small sizes. The z value in the regression test is -0.39 which is the magnitude of the regression coefficient, while the ρ-value of 0.31 is greater than 0.05 which means that H_0 is rejected in other words is not indicated by publication bias in physical activity variables.

Music Listening Factors Affect the Working Memory Capacity

The z value in Table 1 shows a score of 6.17, while the ρ-value is <0.001 which means less than the significance value of 5% (0.05). This means that H0 is rejected, in other words true effect size is not equal to (#) zero (0). This means that the variable of listening to music has a significant influence on working memory capacity. An estimated value of 3.24 (95% CI 12.65; 5.13) showed that listening to music less often decreased working memory capacity than people who listened to music frequently.

The ρ-value in Table 2 is 0.231 > 0.05 which indicates that H_0 is rejected, which means there is no indication of publication bias. Kendall's τ value is the magnitude of the correlation coefficient between effect size and variance, which is 0.21. The z value on the regression test is 1.85 which is the magnitude of the regression coefficient. while the ρ-value in the rank correlation test column of 0.231 is greater than 0.05 which means that H_0 is rejected in other words it is not indicated by publication bias in the variable of listening to music.

Age Factors Affect the Working Memory Capacity

Working memory capacity can be affected by a person's age. Based on research, working memory capacity can decrease with age. This can be due to differences in individual psychological development at the stages of receiving information, retaining information, and recalling information (Loprinzi et al., 2019; Traverso et al., 2020).

Working memory in children has an important role in their learning process and development. Children's working memory capacity can affect their ability to plan, organize, and execute assigned tasks (Judd et al., 2021; Nagaraj et al., 2020). In addition, working memory capacity also affects children's ability to speak, count, and reason.

Children with lower ages are less able to take in as much information into sensory memory as children with higher ages can. The results said that children with a working memory capacity below average, tend to experience difficulties and constraints in academics. They need a harder struggle when it comes to solving math or reading problems. The working memory capacity in each child is different, so parents should not compare their child's working memory capacity with other children who are more accomplished (Laureys et al., 2021; Traverso et al., 2020).

Research shows that visual working memory capacity changes with age, and peaks at age 20. Older people tend to be more easily distracted by irrelevant information, so their ability to ignore distractions is reduced. Other research suggests that older people tend to require more effort to focus on relevant information, as compensation for their diminished ability to retain information in working memory. Older people also tend to have slower response times and poorer performance on working memory tasks (Greene et al., 2020; Korkki et al., 2020).

The ability to work memory in the elderly to respond is very closely related to the state of memory, because in memory stored knowledge learned in the past, how to respond to every event in life, and can be recalled as needed. Cognitive decline in the elderly can include various aspects, including orientation, registration, attention and calculation, memory, and language (Baseler et al., 2022; Stenbäck et al., 2021).

The results of the study found that the older you

get, the more decreased a person's working memory capacity. There are several ways to increase working memory capacity, one of which is to do writing exercises that can help increase short-term memory capacity.

Sleep Quality Factors Affect the Working Memory Capacity

Good sleep quality is very important for the health of the body and brain. One of the adverse effects of sleep deprivation is decreased working memory capacity. Adequate and quality sleep can help increase working memory capacity. Therefore, it is recommended to get enough sleep every night and pay attention to sleep quality to help increase working memory capacity (Adilla et al., 2021; Xie et al., 2019).

Sleep duration also affects working memory capacity. It is important to pay attention to the duration of our sleep to maintain optimal working memory capacity. It is recommended to sleep for 7-9 hours every night to maintain a healthy body and brain. Sufficient duration but not quality such as frequent awakening, can also reduce working memory capacity (Kavanagh & Hourihan, 2020; McCann et al., 2018; Tse et al., 2019).

According to research, poor sleep quality can affect working memory capacity in final-year students. In addition, activities before going to bed such as purification, praying, and dhikr can also affect sleep quality. Therefore, it is important to pay attention to sleep quality to maintain optimal working memory capacity. Some ways that can be done to improve sleep quality include creating a comfortable sleep environment, avoiding caffeine and alcohol consumption before going to bed, and maintaining a regular sleep time (Tse et al., 2019; Vaseghi et al., 2022).

Physical Activity Factors Affect the Working Memory Capacity

Physical activity factors can affect working memory capacity. The type of physical activity that can affect improving working memory capacity is a physical activity that involves coordination and fine motor skills. Dance, or aerobic exercise, can be more effective in improving working memory capacity compared to physical activities that involve only gross movements, such as running or walking. This may be because physical activity involving coordination and fine motor skills can strengthen the connection between the brain and body, which can help improve the brain's ability to retain information in the short term and use it for complex cognitive tasks (Nadira & Daulay, 2022; Russo et al., 2021; Tse et al., 2019).

Regular and consistent physical activity can provide significant benefits for working memory capacity. A study shows that physical activity done for 30 minutes every day for 10 weeks can increase working memory capacity in high school students. Other studies have shown that physical activity done for 60 minutes every day for 12 weeks can improve working memory capacity (Nadira & Daulay, 2022; Tse et al., 2019).

Physical activity increases blood flow to the brain and the production of hormones that can promote the growth of nerve cells in the brain. In addition, physical activity can also improve concentration and focus, which can help improve the ability to pay attention and remember information (Asp et al., 2021; Ponce et al., 2019; Russo et al., 2021). Therefore, it is important to perform physical activity regularly and consistently, with a duration and frequency appropriate to the body condition of each individual to increase working memory capacity.

Music Listening Factors Affect the Working Memory Capacity

Music has a strong influence on a person's working memory capacity. According to a study conducted by researchers from the University of Helsinki, Finland, music can help improve a person's working memory ability. This happens because music can affect brain activity and improve a person's concentration and focus. In addition, music can also help reduce stress and anxiety which can affect a person's working memory ability (Axelsen et al., 2022; Gagnon & Nicoladis, 2021).

The most effective type of music in increasing one's working memory capacity is calm and relaxing music such as music with soothing tones and lyrics, classical music, and Low fidelity (low-fi) music which means music with low fidelity. Lo-fi music is synonymous with soothing sounds, such as raindrops, running water, birdsong, and other nature-related sounds that can have a positive impact on memory. Other studies have shown that music can help improve a person's working memory ability in the long run (Fennell et al., 2021; Vuvan et al., 2020).

Researchers found that people who are used to listening to music have better working memory skills than people who are not used to listening to music. Therefore, listening to music can be one of the effective ways to increase one's working memory capacity. However, keep in mind that the type of music listened to can also affect its effect on a person's working memory ability. Music that is too loud or too complex can interfere with concentration and affect a person's working memory ability. Conversely, calm and relaxing music can help improve one's concentration and focus. Therefore, it is important to choose the right type of music when looking to increase one's working memory capacity (Fennell et al., 2021; Mussoi, 2021; Ribeiro et al., 2022).

Conclusion

This study shows that age, sleep quality, physical activity, and listening to music based on the results of the study proved to be factors that affect working memory capacity. Among these four factors, the age factor cannot be separated from increasing age. Although age is increasing and affects the decline in working memory capacity, factors of good sleep quality, increased physical activity, and more frequent listening to soothing music can be done to increase working memory capacity.

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Conflicts of Interest
In writing this article, we sincerely declare that there are no relevant conflicts of interest that could affect the objectivity and integrity of the results.

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