

Cognitive Conundrums: The Effect of Mixed-Attribute Puzzle Routines on Limiting Cognitive Decline

Lekha Karthik

Abstract

The purpose of this study was to investigate the impact of puzzle routine types on the decline of four major cognitive qualities. The hypothesis posited that if mixed-attribute would mitigate cognitive decline, then the most significant enhancements observed in participants exposed to curated memory, attention, logical, then visuo-spatial puzzles in a social setting (Group 1), followed by the sequence individually (Group 2), then the reverse sequence socially (Group 3), the reverse sequence individually (Group 4), and finally the control group (Group 5). This was grounded on the premise that sequentially challenging tasks would enhance neuroplasticity by progressively reinforcing different cerebral regions, as detailed in Intrinsic Cognitive Load Theory, with social interaction amplifying this effect through neural synchronization (Sweller) (Kas et al.).

The results indicated that Group 1 exhibited the highest improvements: visuo-spatial (16%), logical reasoning (16%), attention (12%), and memory (14%). Group 2 demonstrated moderate gains: visuo-spatial (12%), logical reasoning (8%), attention (8%), and memory (10%). Group 3 recorded: visuo-spatial (10%), logical reasoning (10%), attention (10%), and memory (12%). Group 4 expressed minimal improvement: visuo-spatial (4%), logical reasoning (2%), attention (4%), and memory (3%). The control group (Group 5) exhibited a decline in all cognitive domains (-2%). These findings prove that this particular puzzle regimen significantly enhances cognitive function.

Future research could explore the effects of mixed-attribute puzzle routines on the progression of neurodegenerative disorders or cognitive enhancement across different age groups. These findings have practical implications for developing cognitive enhancement tools and revolutionary strategies for neurodegenerative disease prevention therapy.

Keywords: cognitive decline, germane-intrinsic cognitive load theory, social interaction, visuo-spatial, short-term memory, attention span, logical reasoning, mixed-attribute puzzle routine

Introduction

Human intelligence can be defined as a multitude of abilities. Through this experiment, the effect of the combination of attributes from the current top ranked puzzles, as well as the order in which the puzzles were given, was measured by recording changes in the standard cognitive decline of visuo-spatial reasoning, logical reasoning, attention span, and short-term memory in seniors aged 55 to 80. The main objective of this project was to find a clear link between certain routines and a reduction in cognitive decline. Another underlying objective was understanding the effectiveness of the custom-curated mixed-attribute puzzles versus current high-ranking cognitive puzzles. The research question is particularly relevant to age groups over 55 as this study aimed to find a method to mitigate the cognitive decline that accompanies old age. Moreover, certain neurodegenerative disorders have a 'pre-disorder' stage in which the cognitive qualities enter a declining path. In such cases, the results of this study could be used to help find preventative methods.

Literature Review

Cognitive decline in seniors is a well-documented, expected condition, primarily affecting visuo-spatial reasoning (VSR), logic, attention span, and short-term memory (Ricer et al., 2016). Neuroplasticity, or the brain's ability to reorganize and adapt, remains a fundamental concept in addressing this decline. Sweller's Intrinsic Cognitive Load theory suggests that ordering tasks based on difficulty maximizes learning and retention by encouraging interconnections between cognitive processes. This principle is

especially pertinent in adults, where sequencing tasks to reduce intrinsic difficulty may enhance neuroplasticity (Pollock et al., 2021).

Social interaction has been identified as a key factor in mitigating cognitive decline. Since social interaction increases synchronization, especially in brain regions involved in executive functioning, there will be a slight improvement in task performance (Kas et al, 2019). Moreover, social interaction is associated with increased dopamine production, contributing to the strengthening of memory consolidation and focused attention (Maliske & Kanske, 2022). These findings suggest that social settings amplify the benefits of puzzle routines, providing the necessary neurochemicals involved in short-term memory and attention.

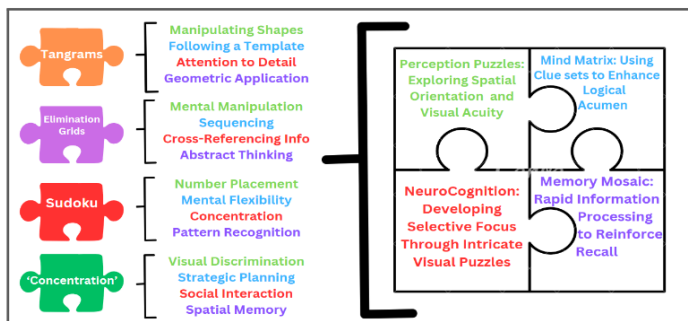
While prior studies provide a basis for the study, gaps remain in understanding how the interaction between the social factor and routine structure will further mitigate cognitive decline. In fact, studies comparing a puzzle structure in an individual vs social setting overlook the cognitive load theory, which should have been kept in control (Bauer, 2005). In addition, a previous study highlighted the importance of cognitive load theory but overlooked the individuality that exists in baseline cognitive abilities which would severely influence outcomes (Thaqib et al., 2018). Thus, there are substantial gaps in studies researching components of mental exercises and their corresponding effects on several cognitive qualities.

Research highlights the importance of targeted cognitive puzzles, with Sudoku, tangrams, and logic grids, offering quantitatively significant improvements in specific cognitive domains (Brophy & Hahn, 2014) (Zhang et al., 2023). The effectiveness of these tools

lies in their ability to activate corresponding cerebral regions: logic in the prefrontal cortex, VSR in the parietal lobe, attention in the frontal lobe, and memory in the temporal lobe (Thirion, 2018). Customized puzzles that combine attributes from these tools may yield superior results, as they target multiple cognitive domains simultaneously. This study will build on prior work by integrating these puzzle components into a single mitigative strategy, structured according to cognitive-load theory.

Methods

In order to create the most effective puzzles to mitigate cognitive decline, associating one attribute that corresponded to each measured quality from each of the top ranked puzzles--sudoku (Brophy & Hahn, 2014), tangrams (Zhang et al., 2023), logic grids (Ciano, 2016), and 'Concentration' (Toril et al., 2016)--to make one custom puzzle for each quality [SEE Bottom (Experimenter)] would ensure that each quality would be able to receive targeted therapy.



Selecting attributes from top-ranked puzzles Credit: Experimenter

Furthermore, logic is more prevalent in the prefrontal cortex, visuo-spatial reasoning in the parietal lobe, attention in the frontal lobe, and short-term memory in the temporal lobe (Thirion, 2018) and social interaction develops neural connections within these exact regions, regulating synchronization of these areas (Kas et al., 2019) [SEE Bottom (Malinske & Kanske, 2022)]. All tests displayed above average internal consistency and test-retest reliability and have undergone rigorous psychometric testing for validity (Vandenberg and Kuse, 1978) (Bauer, 2005) (Pollock et al., 2021) (Ricker et al., 2016). The 1978 Vandenberg Mental Rotations Task tested mental manipulation of 3D objects. An excerpt from a practice Law School Admissions Test measured analytical reasoning. The Test for Variables of Attention recorded selective attention. The Brown-Peterson task tests memory retention and recall using distractors. Ten questions from each test type were compiled in order to create the pre-, mid-, and post-tests [SEE Bottom].

Which two circles contain a configuration of blocks identical to the one in the circle at the left?

Standard

Responses

Question 37: Selective Attention

In the following 20 letters, how many are 'O's?

ccocccococococococcc

Question 2: Numerical Logic

What is the next number in this series: 1, 1, 2, 6, 24, 120, ?

Answer: _____

Question 3: Selective Attention

1) Instruct the participant to remember the following letters in order: XJF

2) As a distractor, ask the participant to count from 1-18 forward and backward.

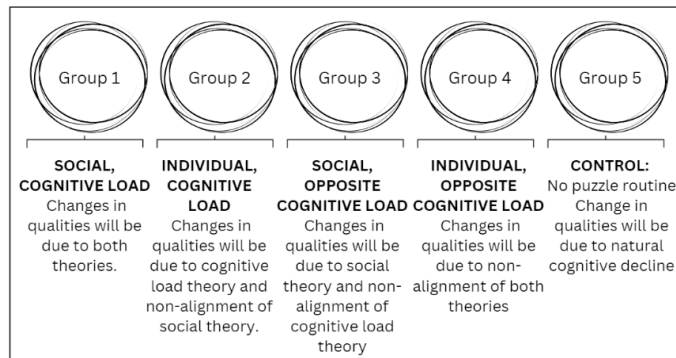
3) Ask the participant to recite the three letters said at the beginning of the exercise.

4) Did the participant recite the correct letters in the correct order? Y N

Sample questions from the VMRT, T.O.V.A, Brown-Peterson Task, and LSAT

Besides social interaction, intrinsic-germane cognitive load theory was factored to create groups [SEE Bottom (Experimenter)]. From a theoretical standpoint, intrinsic load is based on

understanding the inherent difficulty associated with each task and progressing in an easy-hard manner to allow for greater retention of knowledge (Sweller). The rationale for creating the routine order was due to the following findings: the short-term memory pathway becomes crystallized after the age of 20 (Ricker et al., 2016), which would end up making this quality the easiest, complex attentional tasks (such as selective attention) requires speed (Pollock et al., 2021), making it slightly more difficult, logic reasoning generally declines as cognitive flexibility rapidly declines after the age of 50 (Ciano, 2016), and spatial abilities is a perceptual process that is slowed down by aging (Vandenberg and Kuse, 1978) [SEE Bottom (Experimenter)].



Identifying experimental groups and their associated puzzle routine Credit: Experimenter

Results

When measuring the change in short term memory over the course of the experiment, the results kept up with what the hypothesis suggested. However, social interaction was determined to be a more decisive factor. The highest mean delta was recorded in Group 1. Group 4 had a mean displaying a minor effect. In contrast, the control group (Group 5) had a negative mean, showing that the other groups performed significantly better. Moreover, the statistical analysis proved that the data was highly reliable as the maximum range was 0.2.

Table 3
The Effect of Mixed-Attribute Puzzle Routines on Short-term Memory

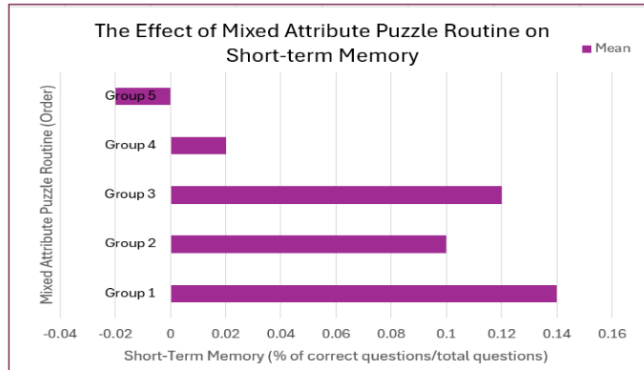
		Δ Short-term Memory (% correct)	
Participant (#)	Group (#)		
1	1		0.10
2	1		0.20
3	1		0.10
4	1		0.20
5	1		0.10
6	2		0.10
7	2		0.20
8	2		0.10
9	2		0.00
10	2		0.10
11	3		0.20
12	3		0.10
13	3		0.10
14	3		0.00
15	3		0.20
16	4		0.00
17	4		0.10
18	4		0.10
19	4		0.00
20	4		0.00
21	5		-0.10
22	5		0.00
23	5		0.10
24	5		-0.10
25	5		0.00

Note: Short-term Memory was a measured attribute in participants subjected to different mixed-attribute puzzle routines. Groups 1-4 were experimental conditions designed to test the impact of cognitive load theory and social interaction on short-term memory in seniors. Group 5 was the control group (given no puzzle routine).

Table 4

Descriptive Statistics for Short-term Memory based on Puzzle Routine				
Group	Mean	Range	Min	Max
1	0.14	0.1	0.2	0.1
2	0.1	0.2	0.2	0
3	0.12	0.2	0.2	0
4	0.02	0.1	0.1	0
5	-0.02	0.2	0.1	-0.1

Note: Values are based on aggregated participant data for each group.



Graph depicting mean delta short term memory for each group as comparison
Credit: Experimenter

Attention span presented similar results; however, the effect of puzzle routines displayed a lesser effect on the quality as compared to short-term memory. Group 1 had the highest mean delta while Group 2 and Group 3 had a very close margin. Group 4 had only a minor positive trend. In contrast, Group 5 had a negative mean. When considering the data statistical analysis, however, there was a greater variance in the data as the maximum range was 0.3. Since all ranges were less than 0.5, this section of the study is valid.

Table 5

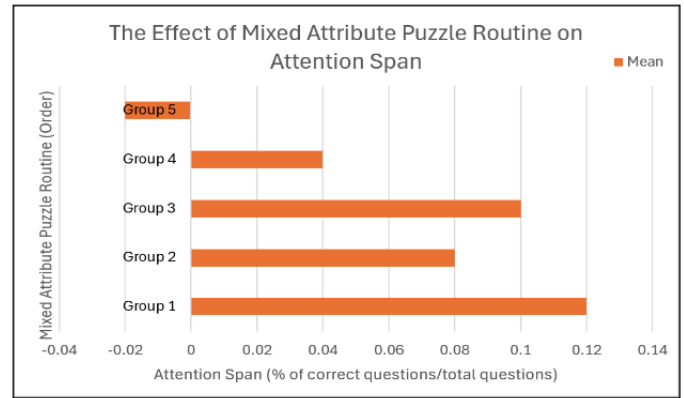
The Effect of Mixed-Attribute Puzzle Routines on Attention Span			
Participant (#)	Group (#)	Δ Attention Span (% correct)	
1	1	0.20	
2	1	0.10	
3	1	0.00	
4	1	0.10	
5	1	0.20	
6	2	0.10	
7	2	0.10	
8	2	0.20	
9	2	-0.10	
10	2	0.10	
11	3	0.20	
12	3	0.10	
13	3	0.10	
14	3	0.20	
15	3	-0.10	
16	4	0.10	
17	4	0.10	
18	4	0.10	
19	4	-0.10	
20	4	0.00	
21	5	0.00	
22	5	-0.10	
23	5	-0.10	
24	5	0.10	
25	5	0.00	

Note: Attention span was a measured attribute in participants subjected to different mixed-attribute puzzle routines. Groups 1-4 were experimental conditions designed to test the impact of cognitive load theory and social interaction on the chronic decline of attention span in seniors. Group 5 was the control group (given no puzzle routine).

Table 6

Descriptive Statistics for Attention Span based on Puzzle Routine				
Group	Mean	Range	Min	Max
1	0.12	0.2	0.2	0
2	0.08	0.3	0.2	-0.1
3	0.10	0.3	0.2	-0.2
4	0.04	0.1	0.1	0
5	-0.02	0.2	0.1	-0.1

Note: Values are based on aggregated participant data for each group.



Graph depicting mean delta attention span for each group as comparison
Credit: Experimenter

In logical reasoning, the data followed a similar pattern but had far more extreme values for each of the groups. The highest mean delta was recorded in Group 1. Group 4 had a mean of 2%, showing a minute difference in the routine. Meanwhile, Group 5 had a negative mean. While most groups had minute variations in spread, Group 5 had a greater value indicating that Group 5 might be minutely skewed. The data had a maximum range of 0.4 in Group 5. This shows that the data was generally accurate, with a medium-high spread.

Table 1

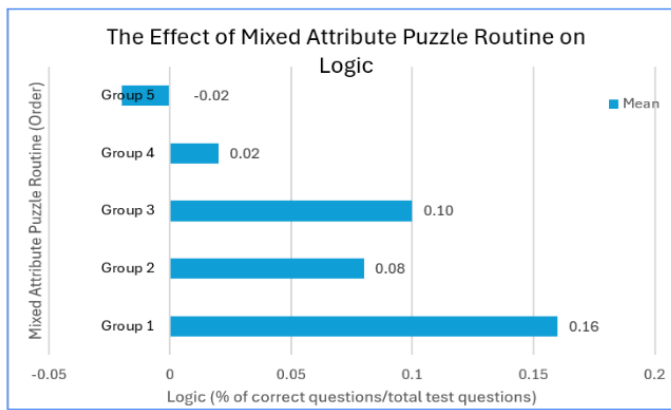
The Effect of Mixed-Attribute Puzzle Routines on Logic		
Participant (#)	Group (#)	Δ Logic (% correct)
1	1	0.20
2	1	0.10
3	1	0.00
4	1	0.30
5	1	0.20
6	2	0.00
7	2	0.10
8	2	0.20
9	2	0.00
10	2	0.10
11	3	0.00
12	3	0.10
13	3	0.10
14	3	0.20
15	3	0.10
16	4	0.10
17	4	0.10
18	4	-0.10
19	4	0.10
20	4	-0.10
21	5	-0.10
22	5	0.00
23	5	0.10
24	5	0.10
25	5	-0.20

Note: Logic was a measured attribute in participants subjected to different mixed-attribute puzzle routines. Groups 1-4 were experimental conditions designed to test the impact of cognitive load theory and social interaction. Group 5 was the control group (given no puzzle routine).

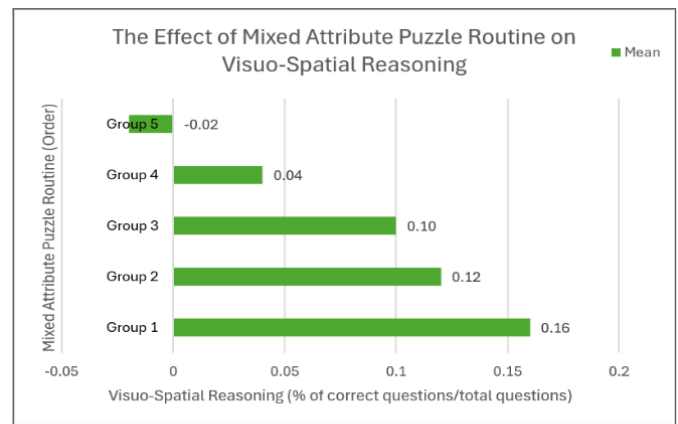
Table 2

Descriptive Statistics for Logic based on Puzzle Routine				
Group	Mean	Range	Min	Max
1	0.16	0.3	0	0.3
2	0.08	0.2	0	0.2
3	0.10	0.2	0	0.2
4	0.02	0.2	-0.1	0.1
5	-0.02	0.3	-0.2	0.1

Note: Values are based on aggregated participant data for each group.



Graph depicting mean delta logical reasoning for each group as comparison
Credit: Experimenter



Graph depicting mean delta logical reasoning for each group as comparison
Credit: Experimenter

Visuospatial reasoning had a slightly different trend than the rest of the qualities as it flipped the positions of Groups 2 and 3. Group 1 had the highest mean delta. Group 4 demonstrated a slighter growth while the control group was negative, meaning that all experimental groups greatly benefited for this quality. The minor askewness in this part (maximum was 0.2) of the observational study demonstrated a significant reliability.

Table 7

The Effect of Mixed-Attribute Puzzle Routines on Visuo-Spatial Reasoning

Participant (#)	Group (#)	Δ Visuo-spatial Reasoning (% correct)
1	1	0.20
2	1	0.10
3	1	0.10
4	1	0.20
5	1	0.20
6	2	0.10
7	2	0.20
8	2	0.10
9	2	0.10
10	2	0.10
11	3	0.10
12	3	0.20
13	3	0.00
14	3	0.10
15	3	0.10
16	4	0.00
17	4	0.10
18	4	-0.10
19	4	0.10
20	4	0.10
21	5	0.10
22	5	0.00
23	5	-0.10
24	5	-0.10
25	5	0.00

Note: Visuo-spatial Reasoning was a measured attribute in participants subjected to different mixed-attribute puzzle routines. Groups 1-4 were experimental conditions designed to test the impact of cognitive load theory and social interaction on the level of visuo-spatial intelligence in seniors. Group 5 was the control group (given no puzzle routine).

Table 8

Descriptive Statistics for Visuo-Spatial Reasoning based on Puzzle Routine

Group	Mean	Range	Min	Max
1	0.16	0.1	0.2	0.1
2	0.12	0.1	0.2	0.1
3	0.10	0.2	0.2	0
4	0.04	0.2	0.1	-0.1
5	-0.02	0.2	0.1	-0.1

Note: Values are based on aggregated participant data for each group.

Discussion of Results

In the project, Group 1 demonstrated the highest results for all qualities [Group 1: visuo-spatial- 16%; logic- 16%, attention- 12%; memory- 14%]. Group 2 and 3 closely followed [Group 2: visuo-spatial- 12%, logic- 8%, attention- 8%, memory- 10% and Group 3: visuo-spatial- 10%, logic- 10%, attention- 10%, memory- 12%], demonstrating that social interaction played a crucial factor in the results. The control group (Group 5) always demonstrated a negative mean (-2% for all qualities). This means that the impact of social interaction and collaboration on reducing chronic cognitive decline was slightly greater than the impact of cognitive load theory and the structure of the routine.

In essence, the data highlights that social interaction plays a slightly more significant role in improving cognitive qualities compared to cognitive load theory used in structuring the puzzle routines. Specifically, the mean improvement due to social interaction (+6%) exceeded that of cognitive load theory (+4%). This finding aligns with existing literature emphasizing social engagement as a neuroprotective effect of social engagement (Kas et al., 2019). In addition, social interaction likely amplified the effectiveness of the custom-curated puzzle routines using motivation, reducing stress, and encouraging various problem-solving methods. Conversely, cognitive load theory's impact likely resulted from its emphasis on progressive challenges, promoting neuroplasticity by forcing participants to adapt with the structure of the routine.

A minor inconsistency between participants that arose during the project was the fact that some seniors had displayed a greater turnout for certain qualities (Participant 1- Group 4 and Participant 5- Group 4). In order to change the wide gaps in knowledge shown in the tests, it was necessary to change the raw data into delta () to exhibit the true effects of the project.

A similar study produced similar results: puzzles delivered in an easy-hard manner allowed for significant improvements in attention span and logic (Al-Thaqib et al., 2018). In Thaqib's team, social interaction was a defining factor but was not more beneficial than cognitive load theory. The variation in results could be explained by the fact that this project introduced the idea of customizing puzzles.

Conclusion

The purpose of this project was to discover if the order in which

approaching puzzles and social interaction could limit the cognitive decline in the elderly. There were two central interpretations of this experiment: social interaction was found to be an exponential factor in the reduction of decline, most likely due to getting acclimated and comfortable with partners, and approaching puzzles in an easy-then-hard manner increased neural connections by building baseline foundations within the respective lobes in the brain.

The hypothesis was somewhat supported by the data since the data displayed that social interaction was surprisingly more helpful than cognitive load theory but still supported that both theories factored in the improvement, changing the order to: Group 1, Group 3, Group 2, Group 4, Group 5 (from greatest to least). In addition, the project helped eliminate chronic cognitive decline of multiple qualities by varying degrees as the control group consistently displayed a negative mean delta.

The findings of this project revealed that the addition of puzzles in the daily routine of seniors limited impairment of crucial cognitive qualities, something that would be very helpful in neurodegenerative disease prevention therapy. To further understand this topic, future studies could discover the effect of mixed-attribute puzzles routines on Neuroplasticity.

References

- Bauer, A. (2005). "Simplifying diagnosis using LSAT: A propositional approach to reasoning from first principles". <https://pspace.org/a/publications/diag04.pdf>
- Brophy, C., & Hahn, L. (2014). Engaging students in a large lecture: An experiment using sudoku puzzles. *Journal of Statistics Education*, 22(1). <https://doi.org/10.1080/10691898.2014.11889690>
- Ciano, L. (2016). "Integrating fluency and accuracy with logic puzzles". *New York State ESOL*, 46(3). <http://idiom.nystesol.org/Summer2016/Summer16-3-4.pdf>
- Kas, M. J., Penninx, B., Sommer, B., Serretti, A., Arango, C., & Marston, H. (2019). A quantitative approach to neuropsychiatry: The why and the how. *Neuroscience & Biobehavioral Reviews*, 97(3), 3-9. <https://doi.org/10.1016/j.neubiorev.2017.12.008>
- Maliske, L., & Kanske, P. (2022). The social connectome - moving toward complexity in the study of brain networks and their interactions in social cognitive and affective neuroscience. *Frontiers in Psychiatry*. <https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsy.2022.845492/full>
- Pollock, B., Harrison, A.G., & Armstrong, I. T. (2021). What can we learn about performance validity from TOVA response profiles? *Journal of Clinical and Experimental Neuropsychology*, 43(4), 412-425. <https://doi.org/10.1080/13803395.2021.1932762>
- Ricker, T. J., Vergauwe, E., & Cowan, N. (2016). Decay theory of immediate memory: From brown (1958) to today (2014). *Quarterly Journal of Experimental Psychology*, 69(10), 1969-1995. <https://doi.org/10.1080/17470218.2014.914546>
- Sweller, J. (2011). "Cognitive load theory - an overview | sciencedirect topics." [Www.sciencedirect.com. https://www.sciencedirect.com/topics/psychology/cognitive-load-theory](https://www.sciencedirect.com/topics/psychology/cognitive-load-theory)
- Al-Thaqib, A., Al-Sultan, F., Al-Zahrani, A., Al-Kahtani, F., Al-Regaiey, K., Iqbal, M., & Bashir, S. (2018). Brain training games enhance cognitive function in healthy subjects. *Medical science monitors basic research*, 24, 63-69. <https://doi.org/10.12659/msmbr.909022>
- Thirion, B. (2018). "Individual brain charting: A high-resolution brain map of cognitive functions". *Humanbrainproject.eu*. <https://www.humanbrainproject.eu/en/follow-hbp/news/individual-brain-charting-a-high-resolution-brain-map-of-cognitive-functions/>
- Toril, P., Reales, J., Mayas, J., & Ballesteros, S. (2016). Video game training enhances visuospatial working memory and episodic memory in older adults. *Frontiers in Human Neuroscience*. <https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2016.00206/full>
- Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, 47(2), 599-604. <https://doi.org/10.2466/pms.1978.47.2.599>
- Zhang, J., Katsuta, N., Takayama, T., Orimo, N., Shibata, N., & Kato, T. (2023). Tangram puzzles in patients with neurocognitive disorders: A pilot study. *Psychiatry International*, 4(4), 404-415. <https://doi.org/10.3390/psychiatryint4040036>