Topic: Memory

by Kunal Sharma, Sarvagya Kaushik, Vansh and V. Bharath Krishna

Cognition and Information Processing in Design

Prof. Sonal Keshwani

TF: Shikha Sharma

Final Project

Indraprastha Institute of Information Technology

Delhi

April 25, 2024

Table of Contents

S.No.	**Title**	**Page No.**
1.	Literature Review	3
2.	Reference Model	6
3.	Research Gaps	7
4.	Bibliography	9

Literature Review

The intersection of memory and design has profound implications across various domains, encompassing cognitive architecture, memory retrieval, and the application of memory in creative processes. Research indicates that memory plays a pivotal role in both individual and collaborative design tasks, influencing creativity and innovation within professional settings [1]. In the realm of cognitive architecture, understanding the foundations of cognitive processes is essential for designing effective educational materials. The intrinsic and extraneous cognitive loads are critical factors; intrinsic load is necessary for learning, while extraneous load should be minimized to enhance learning efficiency. This dichotomy is further explored in terms of task characteristics and learner differences, which tailor learning experiences and manage cognitive load through optimized task design and personalized learning environments [16].

Memory retrieval, particularly from long-term memory storage, is a key enabler of creativity in design. It allows for the utilization of past knowledge in current contexts, enhancing creativity and enabling the generation of innovative design solutions [21]. Furthermore, the association processes, which link known concepts with new ones, are found to be more active during brainstorming sessions, highlighting the role of active memory in creative concept generation [2].

Spatial and visual memory systems also play a significant role, particularly in route learning and the use of virtual environments. These systems enhance memory recall, which is crucial in learning and applying design principles [4]. Additionally, the levels of realism and visual complexity in virtual environments can significantly affect memory recall and cognitive load, pointing to the need for managing these elements to optimize learning and memory efficiency [3,10]. The cognitive load theory underscores the significance of understanding the interaction between memory and cognitive load during design processes. For instance, element interactivity impacts intrinsic cognitive load, suggesting that design techniques like brainstorming, which have higher cognitive demands, may impair information processing if not properly managed [24]. This interactivity is contrasted with methods like TRIZ, which reduce cognitive load and facilitate cognitive flexibility, thereby enhancing design efficiency [22].

In terms of memory's role in creative processes, research highlights the critical nature of both working and long-term memory in supporting creative endeavors. Working memory capacity, for instance, influences decision-making and problem-solving in tasks requiring significant cognitive engagement [17]. Similarly the Semantic memory, its activation and retrieval, is essential for creative ideation and the generation of innovative designs [5]. The density and connectivity of semantic networks can lead to more efficient activation spread, which enhances creative task performance [5, 8]. In contrast, long-term memory contributes to insight problem solving by providing a rich reservoir of past experiences and knowledge that can be applied to new problems [14].

The dynamics between memory and attentional processes also play a crucial role, particularly in insight problem solving. Higher working memory capacity can suppress automatic and unconscious processes that facilitate insight, potentially hindering problem-solving despite its general cognitive benefits [11]. The ability to offload memory items, as discussed in studies on cognitive load and memory load, has been shown to significantly improve performance, especially under high load conditions [12]. This suggests a nuanced relationship between memory capacity and the level of cognitive processing required in various design tasks [13].

Moreover, the interaction of memory with collaborative processes in design settings underscores the complex interplay between cognitive functions and social dynamics. Collaborative stimulation, for instance, can enhance group creativity and idea generation, reflecting the positive impact of memory and cognitive flexibility in team-based design processes [15, 20]. In educational settings, the application of memory research has led to the development of strategies that enhance learning and retention. The spacing effect, retrieval practice, and the use of games and technology-based tools have all been shown to improve memory retention and learning effectiveness [21]. These strategies are particularly relevant in the design of educational interventions that aim to maximize cognitive resources and learning outcomes.

The extensive body of research on memory in design implications highlights the profound impact of cognitive processes on professional practices, educational methodologies, and creative endeavors. The intricate relationships between memory, cognitive load, and creativity not only inform theoretical frameworks but also guide practical applications in design, education, and cognitive training programs [25].

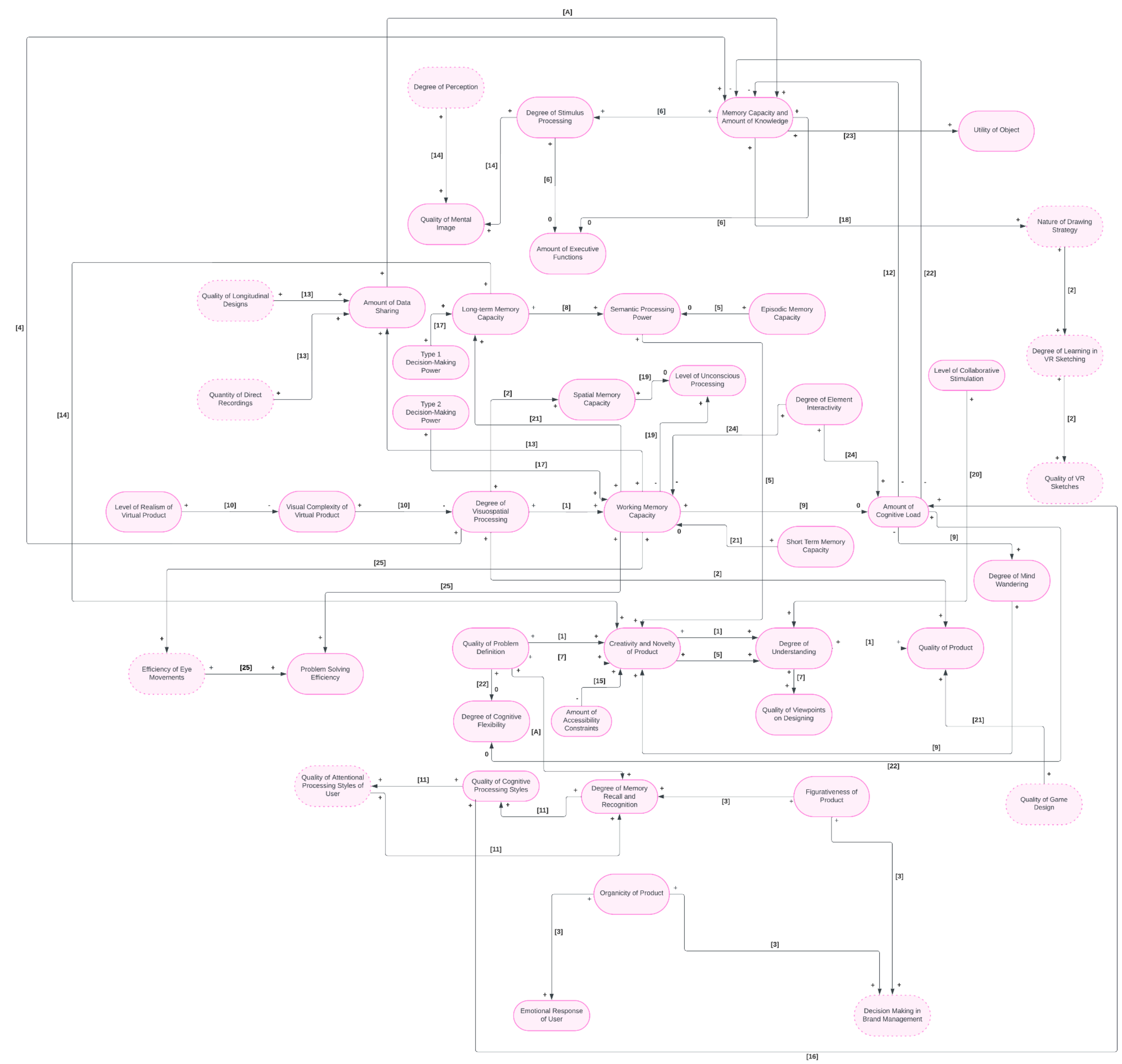
Building on the foundational aspects of memory's influence on design, creativity and novelty further research explores the psychological and cognitive factors that enhance or inhibit creative output [7,11]. For instance, memory load significantly impacts performance, with higher loads leading to decreased performance. The ability to offload memory items can mitigate this effect, suggesting a strategic use of cognitive resources in high-demand scenarios [6, 9]. This is particularly relevant in complex design tasks where cognitive load management can make the difference between successful innovation and cognitive overload [21].

The utility of memory in problem-solving and decision-making processes is highlighted by research into the different types of cognitive processing styles—Type 1 and Type 2 decision-making. Type 1 processes, which are fast and intuitive, are less demanding but might be less thorough, whereas Type 2 processes, which are slower and more analytical, require more cognitive resources but lead to more in-depth and considered decisions [17]. This distinction is critical in design education and practice, where decision-making quality directly affects the efficacy and innovation of design outcomes.

Moreover, the impact of memory on creative processes is evident in the relationships between memory capacity and various cognitive and perceptual processes [11]. Visual memory, for example, is crucial for tasks that involve high levels of detail and accuracy, such as drawing or other visual arts. Studies have shown that experts with better visual memory perform better in these tasks, suggesting that training and enhancement of visual memory could benefit individuals in creative professions [18].

The interaction between working memory capacity and other cognitive functions such as amount of knowledge also reveals complex dynamics that influence creative performance [23]. For instance, while higher working memory capacity may hinder insight problem-solving by inhibiting automatic and associative processes, it enhances other cognitive functions, leading to improved performance in structured problem-solving settings [19]. This dual role of memory underscores the need for a balanced approach to cognitive training that considers the specific requirements and challenges of different creative and professional tasks. Finally, the integration of memory systems in collaborative and educational settings through tools such as games and technology-based learning aids underscores the potential for innovative approaches to enhancing memory and learning. The design of these tools often takes into account the cognitive load theory, ensuring that users are neither overwhelmed nor under-stimulated, thereby maximizing learning efficiency and creative output [20].

Reference Model



Link to the above model: https://lucid.app/lucidchart/bd581282-691c-4dff-bdac-afbcd8314f63/edit?invitationId=inv_c5c35089-38b7-46cb-9eaf-c50b8243c27f&page=0_0#

Research Gaps

Memory Capacity and Amount of Knowledge & Quality of Product:

This research gap indicates a lack of understanding regarding how an individual's memory capacity influences the quality of the final product in design tasks. It suggests a need to investigate how variations in memory capacity impact the cognitive processes involved in design, such as idea generation, problem-solving, and decision-making. Understanding this relationship can provide insights into how memory resources contribute to the creation of high-quality designs.

Working Memory Capacity & Degree of Memory Recall and Recognition:

This gap highlights the need to explore how working memory capacity affects memory recall and recognition specifically within design tasks. It suggests investigating how individuals with different levels of working memory capacity perform in tasks requiring memory retrieval and recognition of design-related information. Understanding this relationship can provide insights into how working memory influences memory-related processes in the context of design.

Level of Collaborative Stimulation & Quality of Cognitive Processing Styles:

This gap suggests a lack of understanding regarding how collaborative stimulation influences the quality of cognitive processing styles exhibited by users during design tasks. It indicates a need to investigate how collaborative environments and interactions affect the cognitive strategies employed by individuals involved in design collaboration. Understanding this relationship can provide insights into how collaborative settings impact cognitive processes and ultimately influence design outcomes.

Quality of Cognitive Processing Styles & Quality of Viewpoints on Designing:

This gap points to a lack of research exploring how the quality of cognitive processing styles relates to the quality of viewpoints on designing. It suggests a need to investigate how individual differences in cognitive processing styles, such as analytical versus intuitive approaches, influence the perspectives and insights generated during the design process. Understanding this relationship can provide insights into how cognitive styles shape design viewpoints and decision-making processes.

Problem Solving Efficiency & Degree of Cognitive Flexibility:

This gap indicates a need to explore the relationship between problem-solving efficiency and cognitive flexibility in design tasks. It suggests investigating how individuals with higher cognitive flexibility demonstrate more efficient problem-solving strategies in design contexts. Understanding this relationship can provide insights into the cognitive mechanisms underlying effective problem-solving and adaptation to changing design challenges.

Working Memory Capacity & Quality of Mental Image:

This research gap indicates a need to understand how an individual's working memory capacity influences the quality of mental images in design tasks. It suggests investigating how variations in working memory capacity impact the ability to form, manipulate, and retain mental representations of design-related information. Understanding this relationship can provide insights into how working memory resources contribute to the visualization and manipulation of design concepts, ultimately influencing the quality of design outcomes.

Bibliography

[1] Campbell, G., Hay, L., Gilbert, S., McTeague, C., Coyle, D., & Grealy, M. (2024). *Functional activity and connectivity during ideation in professional product design engineers.* Design Studies. https://doi.org/10.1016/j.destud.2024.101247

[2] Chaniaud, N., Fleury, S., Poussard, B., Christmann, O., Guitter, T., & Richir, S. (2023). *Is virtual reality so user-friendly for non-designers in early design activities? Comparing skills needed to traditional sketching versus virtual reality sketching.* Design Science, 9(Article e28). https://doi.org/10.1017/dsj.2023.27

[3] De Lencastre, P., Machado, J. C., & Costa, P. (2023). *The effect of brand names and logos figurativeness on memory: An experimental approach*. Journal of Business Research, 164, 113944. https://doi.org/10.1016/j.jbusres.2023.113944

[4] Galasso, C. S. (2023). *Memory studies and design? The mnemotopic approach.* Memory Studies, 16(6), 1628-1641. https://doi.org/10.1177/17506980231202853

[5] Gerver, C. R., Griffin, J. W., Dennis, N. A., et al. (2023). *Memory and creativity: A meta-analytic examination of the relationship between memory systems and creative cognition*. The Psychonomic Society, 30(8), 2116–2154. https://doi.org/10.3758/s13423-023-02303-4

[6] Hay, L., Cash, P., & McKilligan, S. (2020). *The future of design cognition analysis.* Design Science, 6, e20. https://doi.org/10.1017/dsj.2020.20

[7] Hay, L., Duffy, A. H. B., McTeague, C., Pidgeon, L. M., Vuletic, T., & Grealy, M. (2017). *A systematic review of protocol studies on conceptual design cognition: Design as search and exploration.* Design Science, 3(Article e10). https://doi.org/10.1017/dsj.2017.11

[8] Hay, L., Duffy, A. H. B., McTeague, C., Pidgeon, L. M., Vuletic, T., & Grealy, M. (2017). *Towards a shared ontology: A generic classification of cognitive processes in conceptual design.* Design Science, 3, e7. https://doi.org/10.1017/dsj.2017.6

[9] Huang, Y., Song, X., & Ye, Q. (2024). *Mind wandering and the incubation effect: Investigating the influence of working memory capacity and cognitive load on divergent thinking.* Thinking Skills and Creativity, 52, 101499. https://doi.org/10.1016/j.tsc.2024.101499

[10] Lokka, I. E., & Çöltekin, A. (2019). *Toward optimizing the design of virtual environments for route learning: Empirically assessing the effects of changing levels of realism on memory.* International Journal of Digital Earth, 12(2), 137–155. https://doi.org/10.1080/17538947.2017.1349842

[11] Lyadurai, L., Visser, R. M., Lau-Zhu, A., Porcheret, K., Horsch, A., Holmes, E. A., & James, E. L. (2019). *Intrusive memories of trauma: A target for research bridging cognitive science and its clinical application.* Clinical Psychology Review, 69, 67-82. https://doi.org/10.1016/j.cpr.2018.08.005

[12] Morrison, A. B., & Richmond, L. L. (2020). *Offloading items from memory: individual differences in cognitive offloading in a short-term memory task.* Cognitive Research, 5(1). https://doi.org/10.1186/s41235-019-0201-4

[13] Ofen, N., Tang, L., Yu, Q., & Johnson, E. L. (2019). *Memory and the developing brain: From description to explanation with innovation in methods.* Developmental Cognitive Neuroscience, 36, 100613. https://doi.org/10.1016/j.dcn.2018.12.011

[14] Okada, T., & Yokochi, S. (2024). *Process modification and uncontrollability in an expert contemporary artist's creative processes.* Journal of Creative Behavior. https://doi.org/10.1002/jocb.635

[15] Oliva, M. T., & Storm, B. C. (2023). *Internet use and creative thinking in the Alternative Uses Task.* Journal of Creative Behavior, 57(7), 796-811. https://doi.org/10.1002/jocb.618

[16] Paas, F., & van Merriënboer, J. J. G. (2020). *Cognitive-Load Theory: Methods to Manage Working Memory Load in the Learning of Complex Tasks.* Current Directions in Psychological Science, 29(4), 394-398. https://doi.org/10.1177/0963721420922183

[17] Padilla, L. M., Creem-Regehr, S. H., Hegarty, M., et al. (2018). *Decision making with visualizations: A cognitive framework across disciplines.* Cognitive Research, 3(1), 29. https://doi.org/10.1186/s41235-018-0120-9

[18] Perdreau, F., & Cavanagh, P. (2015). *Drawing experts have better visual memory while drawing.* Journal of Vision, 15(5), 5. https://doi.org/10.1167/15.5.5

[19] Salmon-Mordekovich, N., & Leikin, M. (2022). *The Cognitive–Creative Profiles of Insightful Problem Solvers: A Person-Centered Insight Study.* Journal of Creative Behavior, 56(3), 396-413. https://doi.org/10.1002/jocb.536

[20] Sauder, J., & Jin, Y. (2016). *A qualitative study of collaborative stimulation in group design thinking.* Design Science, 2(Article e4). https://doi.org/10.1017/dsj.2016.1

[21] Schimanke, F., Ribbers, S., Mertens, R., & Vornberger, O. (2015). *Implications of short term memory research for the design of spaced repetition based mobile learning games.* In 2015 IEEE International Symposium on Multimedia (ISM). https://doi.org/10.1109/ISM.2015.13

[22] Shealy, T., Gero, J., Hu, M., & Milovanovic, J. (2020). *Concept generation techniques change patterns of brain activation during engineering design.* Design Science, 6(Article e31). https://doi.org/10.1017/dsj.2020.30

[23] Shen, D., Yao, X., Bao, D., & Yu, Y. (2023). *Content categorization for memory retrieval: A method for evaluating design performance.* PloS One, 18(1), e0280459. https://doi.org/10.1371/journal.pone.0280459

[24] Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). *Cognitive architecture and instructional design: 20 years later.* Educational Psychology Review, 31(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

[25] Yeh, Y.-C., Tsai, J.-L., Hsu, W.-C., & Lin, C. F. (2014). *A model of how working memory capacity influences insight problem solving in situations with multiple visual representations: An eye tracking analysis.* Thinking Skills and Creativity, 13, 153-167. https://doi.org/10.1016/j.tsc.2014.04.003