Long-Term Memory and Prior Knowledge

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Long–term memory is a highly efficient cognitive system that stores infinite amounts of information for indefinite periods of time. Integral to our survival, long-term memory has evolved for strategic planning of the future based on prior knowledge from past experiences, helping us to interpret and understand the present (Klein et al., 2010). In modern times, long-term memory uses top-down processes by relying on prior knowledge and expectations to help us navigate diverse situations at any point in time (Klein et al., 2010). This influences product design as intuitiveness of a product is determined by whether a product aligns with established mental frameworks developed from these past experiences (Asikhia & Setchi, 2016). Therefore, product designers are pivotal in aligning these expectations to craft intuitive user experiences (Asikhia & Setchi, 2016). Beyond its unlimited and infinite storage capacity, long-term memory is characterized as highly organized, intricately connected, and constantly evolving (Camina & Güell, 2017). This essay explores several theories that support these characteristics of long-term memory, which is later applied in an evaluation of the Reformation in-store shopping experience to assess the downfalls of their technology enhanced process in relation to the way humans naturally store information.

The Structures of Long-Term Memory

Top-down processing seamlessly guides our visual search, perception, and pattern recognition, leveraging prior knowledge to guide our attention as we navigate the environment around us. From the initial perception of stimuli through contrast to the formation of recognizable patterns, the feedforward process continually informs our brain, integrating new information into highly structured prior knowledge. The following sections explore various theories on the cognitive structures of knowledge and the interplay between new and prior knowledge.

Schemata And Scripts

At the core of the highly organized framework of long-term memory is the concept of schemata, or "semantic memory structures that help people organize new information they encounter" (Radvansky & Tamplin, 2012). These units of knowledge help people encode and retrieve information over a lifetime. The strength and accuracy of this process are influenced by the saliency of an event or item, with more emotionally charged situations being encoded more deeply into our memory (Webb & Dennis, 2019). Associative, adaptable, and flexible, schemata can "combine many different elements of an event or experience" and constantly evolve from the continuous incorporation of new information (Ghosh & Gilboa, 2013; Webb & Dennis, 2019).

Scripts, a subset of schemata, store information belonging to the "temporally ordered sequence of events that frequently occur in the world" (Radvansky & Tamplin, 2012). Part of procedural memory, scripts are automatically retrieved to guide behavior in complex procedures, involving both motor and cognitive skills (Camina & Güell, 2017). Examples include navigating restaurant etiquette and riding a bike. Described as "behavioral guides," scripts act as instructions

for how to act in both new and familiar situations, reducing anxiety and human error (Camina & Güell, 2017). In unfamiliar contexts, individuals try to match a script with the current situation as closely as possible to understand how to behave in the context (Camina & Güell, 2017).

Mental Models

Beyond schemata and scripts, mental models are cognitive representations formed by people's unique life experiences, guiding people's interactions with their external environment (Jones et al., 2011). However, they differ from schemata as mental models are more flexible, using "multiple schemata to represent or simulate an unfamiliar situation" (Jones et al., 2011). While schemata pertain more to routine and stable situations, mental models can be formed in the absence of a schema in unfamiliar events (Al-Diban, 1970). Similar to the flexibility of mental models, frames describe knowledge frameworks but in the broader societal context.

Frames

An influential contribution to theories of knowledge representation, frame theory has evolved through the works of psychologists, anthropologists, and notably, computer scientist Marvin Minsky. Contemporarily defined as a "general meaning context within which social actors interpret action," frames act as "public aligners" (Wood et al., 2018). Unlike schemas, which are more subjective and deemed "personal aligners", frames align individuals' schemas to a shared situation representing its bigger social context (Wood et al., 2018). Despite the differences between schemas, scripts, mental models, and frames, these frameworks all explain how people interpret and navigate situations, playing a role in reducing anxiety and minimizing human error.

Memory Representations

Exploring how these structures are represented within the mind, two theories emerge explaining memory as interconnected webs of information: spatial models and semantic networks. The spatial model proposes that during retrieval, semantic memories, or general facts, concepts, and meanings of words, are represented in a three-dimensional space, where "association strength is designated by the distance between two points" (Zemla & Austerweil, 2018). Essentially, the probability of cueing one concept after retrieving another depends on their spatial proximity and contextual relationship (Zemla & Austerweil, 2018).

Semantic networks offer an alternative explanation emphasizing the associative and implicit nature of memories. This model presents semantic memory as an organized network of concepts (nodes) that are "connected to semantically similar concepts by edges." (Zemla & Austerweil, 2018). Nodes can be cued into recall through "causal relations, featural similarity,

subordinate or superordinate relations, or temporal co-occurrence" (Zemla & Austerweil, 2018). Semantic networks are defined by their interconnectedness, allowing people to quickly retrieve information from a series of activations recalling related information.

Memory Search

Considering memory retrieval, various theories explain how memories are recalled from the knowledge network, one notable theory being the spreading activation model. The theory postulates that the interconnected and associative nature between nodes determine the likelihood of retrieving concepts that share edges and common relevance (McNamara & Altarriba., 1988). Traces, such as the word “water,” prime associated concepts like “fish,” exhibiting how activation spreads and “primes the recall of other semantically related items” (Wheeler & Gabbert, 2017). The strength or distance between nodes plays a pivotal role, where “more active traces are retrieved faster than less active traces” (McNamara & Altarriba., 1988).

Another theory of memory search is the encoding-specificity principle, which states that the environment in which information is encoded impacts its retrieval (Wheeler & Gabbert, 2017). It infers that memories are more easily retrieved if it occurs in the same environment they were encoded in (Wheeler & Gabbert, 2017). Importantly, spreading activation and the encoding-specificity principle are not mutually exclusive; they can work together to comprehensively explain how memories may be recalled (Wheeler & Gabbert, 2017). Additionally, associations within the cognitive network can be forged and strengthened through metaphors.

Metaphors

Metaphors serve as cognitive methods to establish stronger associations between nodes in the semantic network, effectively bridging the gap between what people don’t know to what people do know (Asikhia & Setchi, 2016). Through recurring experiences, the relation between a concept and its associated behavior gradually forms a link in the subconscious mind, transforming into prior knowledge to allow for assimilation of new information (Asikhia & Setchi, 2016; Lakoff & Johnson, 2017). Regarding product design, establishing metaphors can yield "interesting patterns that can subsequently be recruited for interaction with minimum cognitive effort, and in a quicker time frame,” ultimately enhancing usability (Lakoff and Johnson, 1980).

Consolidation of Knowledge

Transitioning to knowledge consolidation, the assimilation and accommodation model postulated by Jean Piaget (1976) explains memory storage as a constantly evolving file system of information. In this model, assimilation occurs first, integrating novel information into existing mental frameworks (Kuhbandner, 2020). If assimilation fails, accommodation is triggered,

creating new schema and adapting old ones when the information is inconsistent with one's prior knowledge (Kuhbandner, 2020). This sequential duo enhances cognitive efficiency and reduces cognitive load, only reverting to the more effortful process of accommodation "in order to cope with things that don't fit those existing frameworks" (Spachtholz & Kuhbandner, 2017).

Another knowledge acquisition model, accretion, tuning, and restructuring present themselves as "different modes of learning" (Rumelhart & Norman,1976). Accretion, requiring the least amount of effort, involves the accumulation of factual knowledge into our long-term memory (Rumelhart & Norman,1976). Tuning refers to the gradual modifications of schemata to align them with "the functional demands placed on these categories" and require more effort than accretion (Rumelhart & Norman, 1976). Lastly, restructuring is the complete reconstruction of a current knowledge base to help interpret novel information, imposing the most amount of cognitive load and time to complete (Rumelhart & Norman, 1976). Considering expertise, experts of a specific knowledge domain can retrieve domain specific information faster than novices, emphasizing the importance of considering the audience's expertise levels in product design.

Case Study: Reformation In-Store Shopping Experience

Reformation is a sustainable women's fashion brand and has made changes in recent years to its in-store process of browsing through clothes, trying them on, and checking them out through the addition of "smart" fitting rooms and touch screen support. Some fashion and technology aficionados might relish this enlightened and futuristic experience. However, others might find the new processes confusing and uncomfortable, as it enforces a big shift in the mental models and schemas established from our typical experiences shopping in a retail store.

Minimalist Presentation

At first glance, the minimalist appearance of clothing racks, featuring one item per size, as can be seen in Figure 1, may cause discomfort and a sense of emptiness. This format deviates from customers' expectations of the in-store shopping experience, potentially causing conflict with customers' established schemas and mental frameworks. Traditionally, clothing inventory is more abundant and diverse in sizes, leading to the potential of customers feeling excluded, confused, and even disengaging. To bridge cognitive dissonance, accommodation must occur to better understand the novel experience. To further minimize cognitive load and aid assimilation, I recommend introducing customers to the store's layout and practices before they begin shopping to get them familiar with the environment.

Figure 1

Clothing Rack

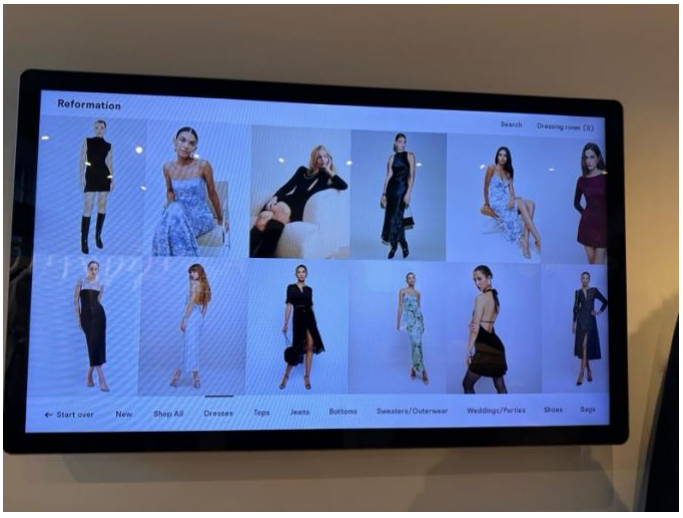
Note. The minimalist clothing rack showcases one size per article of clothing.

Tablet-Based Clothing Requests

Upon finding an item of interest, customers can use in-store digital screens, depicted in Figure 2, to select items and sizes they would like to try on. With this hands-off approach, discomfort and confusion might occur for customers used to traditional, employee-to-customer interactions, although it might be more favorable to introverts and tech enthusiasts. Regardless, this process conflicts with established scripts of in-store shopping procedures, causing the need to establish new mental frameworks. To reduce overwhelm, I recommend maintaining traditional interactions and offering assistance for those that prefer it or are unfamiliar with their process.

Figure 2

In-Store Tablet – Selecting Items to Try On



Note. The tablet depicts the online retail shop and allows customers to add items into a dressing room.

Technology Enhanced Fitting Rooms

Once in the fitting room, customers encounter various technological features, including personalized lighting and music changes, along with an interactive tablet for making additional clothing requests. While these enhancements can be intriguing, the tablet, as seen in Figure 3, might overwhelm less tech-savvy customers. The seemingly magical appearance of requested clothing in the fitting room wardrobe (Figures 4.1 and 4.2) might discomfort customers as the situation is unfamiliar and traditional procedures involve requesting an actual sales representative to retrieve the desired items. People that may like the traditional method of interacting with an employee for additional sizing and styling recommendations may feel at a loss with the limited interaction they have in the store. Again, this would require cognitive effort to establish or adapt frameworks that can help the individual understand how to best engage in the new procedures. To ensure an intuitive experience, I recommend employees assess customers' technology familiarity and shopping preferences throughout, aligning their store's procedures with customers' existing mental models as best as possible.

Figure 3

Fitting Room Tablet

Note. The tablet shows the online retail store and allows customers to add additional items or sizes into the wardrobe.

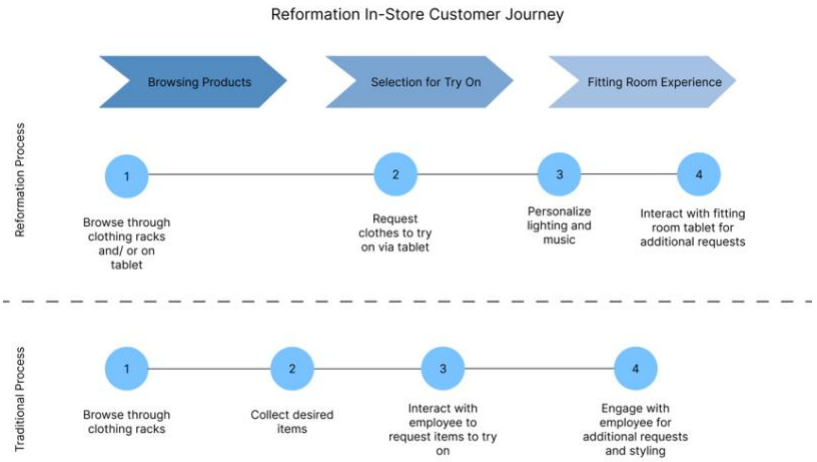
Figures 4.1 and 4.2

Fitting Room Wardrobe

Note. The wardrobe comes stocked with customer's requested items and adds additional items they may request in the fitting room.

Figure 5

Reformation Customer Journey



Note. This journey map does not depict the entire shopping experience of the Reformation store and only showcases particular phases in the process for relevance and demonstration purposes.

Conclusion

Long term memory is a sophisticated cognitive system that has evolved for strategic planning and effortless daily interactions. Its infinite capacity, adaptability, and interconnectedness play crucial roles in storing information, readily accessible in situations resembling past experiences and expectations. An individual's prior knowledge enables top-down processing, guiding necessary behaviors like visual search and decision-making. Essential not only for basic human survival but also in product design, product designers carry the responsibility of crafting intuitive and usable experiences that align with our established knowledge frameworks and help guide seamless adaptation of cognitive structures.

References

Al-Diban, S. (1970, January 1). *Mental Models*. SpringerLink. https://link.springer.com/referenceworkentry/10.1007/978-1-4419-1428-6_586#:~:text=Schemas%20and%20Mental%20Models&text=In%20contrast%20to%20schemas%2C%20mental,situation%20or%20an%20unknown%20problem.

Asikhia, O. K., & Setchi, R. (2016). Linking design intention and users' interpretation through image schemas. *IFAC-PapersOnLine*, *49*(19), 283–288. https://doi.org/10.1016/j.ifacol.2016.10.550

Camina, E., & Güell, F. (2017, June 19). *The neuroanatomical, neurophysiological and psychological basis of memory: Current models and their origins*. Frontiers. https://www.frontiersin.org/articles/10.3389/fphar.2017.00438/full

Jones, N. A., Ross, H., Lynam, T., Perez, P., & Leitch, A. (2011). Mental models: an interdisciplinary synthesis of theory and methods. *Ecology and Society*, *16*(1). https://doi.org/10.5751/es-03802-160146

Ghosh, V. E., & Gilboa, A. (2013). What is a memory schema? A historical perspective on current neuroscience literature. *Neuropsychologia*, *53*, 104–114. https://doi.org/10.1016/j.neuropsychologia.2013.11.010

Klein, S. B., Robertson, T. E., & Delton, A. W. (2010, January). *Facing the future: Memory as an evolved system for planning future acts*. Memory Cognition. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3553218/

Kuhbandner, C. (2020). Real-world objects are represented in visual long-term memory both as unbound features and as bound objects. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.580667

Lakoff, G., & Johnson, M. (2017). *Metaphors We Live By*. University of Chicago Press.

McNamara, T. P., & Altarriba, J. (1988). Depth of spreading activation revisited: Semantic mediated priming occurs in lexical decisions. Journal of Memory and Language, 27(5), 545–559. doi:10.1016/0749-596x(88)90025-3

Radvansky, G. A., & Tamplin, A. K. (2012). Memory. *Encyclopedia of Human Behavior*, 585–592. https://doi.org/10.1016/b978-0-12-375000-6.00229-9

Piaget, J. (1976). Cognitive Development in Children: Piaget Development and Learning. Journal of Research in Science Teaching, 2, 176-186. https://doi.org/10.1002/tea.3660020306

Rumelhart, D. E., & Norman, D. A. (1976). *Accretion, Tuning and Restructuring: Three Modes of Learning*. https://doi.org/10.21236/ada030406

Spachtholz, P., & Kuhbandner, C. (2017, September 18). *Visual long-term memory is not unitary: Flexible storage of visual information as features or objects as a function of affect - cognitive, affective, & behavioral neuroscience*. SpringerLink. https://link.springer.com/article/10.3758/s13415-017-0538-4

Webb, C. E., & Dennis, N. A. (2019, October 4). *Memory for the usual: The influence of schemas on memory for non-schematic information in younger and older adults*. Cognitive Neuropsychology. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8919503/

Wheeler, R. L., & Gabbert, F. (2017, October 27). *Using self-generated cues to facilitate recall: A narrative review*. Frontiers in psychology. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5664228/

Wood, M. L., Stoltz, D. S., Van Ness, J., & Taylor, M. A. (2018). Schemas and Frames. Sociological Theory, 36(3), 244–261. doi:10.1177/0735275118794981

Zemla, J. C., & Austerweil, J. L. (2018, March). *Estimating semantic networks of groups and individuals from fluency data*. Computational brain & behavior. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6555428/#:~:text=One%20popular%20and%20classic%20theory,to%20nodes%20and%20edges%2C%20respectively.