論文要約

Thesis summary

Re-examining the underlying mechanisms of the Hebb repetition effect in human memory

（記憶におけるヘッブ反復効果の生起メカニズムの再検討）

ARAYA OROZCO CLAUDIA

The present thesis aimed to explore Hebb repetition learning in complex span tasks and its underlying mechanisms, Chapter 1 portrays a general introduction to this topic focusing on memory for serial order and the relationship between short-term memory (STM), working memory (WM) and long-term memory (LTM).

In his seminal work, Lashley (1951) emphasized the significance of learning serial order information in human daily life, yet limited efforts were made to deeply understand it, paving the way for research on serial order information learning. Building on this idea, Donald Hebb (1961) devised an experimental paradigm in which the same sequence of digits was repeated every third trial in an immediate serial recall task. He discovered that performance on the repeated sequence improved with each repetition, while performance on the non-repeated sequences remained consistent. This phenomenon of increased recall accuracy on repeated lists is now known as the Hebb repetition effect (Henceforth referred to as the Hebb effect) and the long-term learning resulting from repetition is referred to as Hebb repetition learning.

Hebb repetition learning serves as a perfect example of the interaction between STM, WM, and LTM. Through the Hebb repetition paradigm, we can see information held in STM and WM that is processed repetitively and eventually transfer to LTM, once it is stored in LTM it is retrieved every time that sequence is presented, to help on correctly recall the list. Thus, this form of learning has gained interest for its closeness to language acquisition. It serves as a valuable tool for understanding that link between STM and LTM, especially in the learning of serial-order information. Hebb repetition learning is considered a paradigmatic example of long-term sequence learning and a laboratory analogue of naturalistic word-form acquisition. Evidence suggests a single mechanism for learning phonological sequences that supports both word learning and Hebb repetition learning.

In Chapter 2, an overview on previous research related to the Hebb repetition paradigm is presented. The Hebb effect demonstrated through immediate serial recall tasks, specifically simple span tasks, has been studied extensively, it implies that lists maintained for immediate recall leave LTM traces which are later used for its recall, those retained sequence of information in STM gradually develops into a stable LTM trace. While the precise mechanism underlying the effect remains unclear, it appears that learning in Hebb repetition primarily involves acquiring knowledge about the serial order of items in the repeated list and that repetition of a full uninterrupted list is necessary. Up until now, the mechanism that better explains this phenomenon is chunking, that is, the LTM representation of a list that underlies the Hebb effect is acquired as one unit, and retrieved as one unit, rather than as a collection of pair-wise associations of items that can be acquired and retrieved independently.

Chapter 3 presents the first study which had as an objective to confirm the occurrence of the Hebb effect in complex span tasks. Previous studies have suggested that the Hebb effect may not occur in complex span tasks due to the secondary task interleaved between the memory items (i.e., distractors). However, Oberauer et al. (2015) provided initial evidence of the Hebb effect in a complex span paradigm. Building upon these findings, a series of experiments were conducted to further investigate this phenomenon. Experiment 1 replicated Oberauer et al. (2015) second experiment, confirming the presence of the Hebb effect in complex span tasks. Additional variables that could influence the effect were considered in Experiments 2 and 3, it has been debated if the Hebb effect may occur during either or both encoding and recall phases. Therefore, these experiments introduced distractors during both the encoding and recall phases, aiming to determine if the Hebb effect occurs when memory items are never experienced in immediate succession. Additionally, if Hebb repetition learning that occurs during a complex span task can be transferred to a simple span task was examined. The results confirmed the occurrence of the Hebb effect in complex span tasks despite the distractors and provide newfound evidence of a transfer effect, participants exhibited higher accuracy for the Hebb list compared to filler lists in a simple span task included at the end of the experiment, indicating that learning during complex span tasks can be transferred to simple span tasks. These results challenge previous conclusions in relation to Hebb repetition learning and suggests the need for a revision of the existing theoretical understanding.

Chapter 4 described the second study, which aimed to replicate and expand on the results obtained from the initial experiments, focusing on the similarity between memory items and distractors. Experiment 4 sought to replicate the findings in an online setting, while Experiments 5 and 6 explored the effect of less distinctive distractors. We increased the challenge of creating chunks by making memory items and distractor stimuli less discriminable: Both list items and distractors were Latin letters. The results consistently demonstrated the presence of the Hebb repetition and transfer effects, despite interruption of the repeated sequence with the secondary task at both encoding and recall phases. Two possible explanations were proposed: a) The learning of position-item associations in LTM; b) The creation and learning of chunks of only the memory items, excluding the distractors.

The third study, described in Chapter 5 aimed to unravel the mechanism underlying the Hebb effect in complex span tasks. The initial assumption was that the Hebb effect relies on chunking in simple span but in position-item associations in complex span tasks. Three experiments were conducted to evaluate that assumption. Experiment 7 examined the possibility of a transfer effect from a complex span to a partially repeated simple span task (i.e., repetition of only the odd or even positions), the results showed weak evidence against a transfer effect. Experiment 8 explored the Hebb effect in a partially repeated complex span task, results showed strong evidence against Hebb repetition learning. The findings from

Experiment 7 and 8 suggest that the underlying mechanism might not be position-item associations. With that in mind, we proposed that the same learning mechanism likely operates in both simple and complex span paradigms. That would allow for the transfer effects to be symmetrical, as opposed from our initial assumptions, learning transfer from simple span to complex span would be possible. Experiments 9a and 9b aimed to gather evidence on that front with two different distractor tasks, the results showed evidence in favor of learning transfer from a simple span task to a complex span task with distractors of different difficulty. These results suggest that the chunk representation created along the simple span task is still useful when facing a complex span task with either semantic or phonological distractor tasks. We conclude that the not-repeated distractors in a complex span task are functionally different from interleaved not-repeated list items.

These results lead to the question: How are distractors in a complex span Hebb repetition task being processed? Chapter 6 describes the study that focused on answering that question. One possibility is that the distractors do not become a part of the LTM representation for the repeated sequences. Experiment 10 explored the role of distractors in Hebb repetition learning and tested that hypothesis. Three conditions were designed to manipulate the repetition of memory items and distractors: Repeating only the items of the memory list, repeating only the distractors, and repeating both items and distractors. The repetition of distractors, although processed in WM, had no impact in Hebb repetition learning, implying that the distractors are excluded from the LTM trace of learned sequences.

Overall, the series of experiments included in this thesis provide evidence for the presence of the Hebb effect in complex span tasks, an insight on distractors processing within list repetitions, and evidence for a shared learning mechanism with simple span tasks, that is, chunking.

Moreover, Chapter 7 presents with data on the role of repetition awareness. The Hebb effect has historically been known as an example of implicit learning. That is, the repetitions occur unbeknown to the participants and they do not become aware of that repetition along the experiment but their performance in the repeated list is higher than on the non-repeated lists. To explore this statement, we also collected awareness data as established in previous research (McKelvie, 1987), with an awareness questionnaire (i.e., Did you notice anything particular about the procedure?) and a recognition test (i.e., Four lists will be presented and the participant needs to choose which one corresponds to the repeated one). The results showed that on average 46% of the participants did not notice the repetition but most of them could correctly recognize the repeated sequence. Given recent findings showing that Hebb repetition learning is not implicit (Musfeld, et al., 2023) we expanded our analysis to explore any differences between participants who claimed to have noticed the repetition and those who did not. We divided the participants in two groups (i.e., aware and unaware) and re-analyze the memory accuracy data, in line with these recent findings the results showed a Hebb effect in the aware data but not in the unaware data.

At last, Chapter 8 includes a summary of the main findings, theoretical implications, limitations, future steps and conclusions. By using complex span memory tasks to study the Hebb effect, the present thesis contributes to our understanding of Hebb repetition learning and its underlying mechanisms. It is an important piece of knowledge to better understand the information exchange between STM and LTM, particularly in serial-order information. Nevertheless, a limitation of our study is that participants were mindful of memory items and distractors, that knowledge of which items need to be remembered might have an effect on Hebb repetition learning. Future studies could investigate at which point in time participants need to discern the to-be remembered stimuli from those they can forget in order to exclude the latter from the LTM representation that builds up in Hebb repetition learning.

To conclude, our main finding is that the creation of LTM traces by Hebb repetition learning occurs through the same mechanism in both simple and complex span tasks. This mechanism is likely to be the acquisition of a chunk that represents the memory items in their correct order but excludes the distractors. This finding indicates how humans flexibly learn regularities in our linguistic environment and possibly in the general world, opening up the way to divert from vocabulary learning and expand to broader aspects of learning, namely, one that is not restricted to successive sequences of elements.