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Rapid Consolidation of New Knowledge in Adulthood Via Fast Mapping

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Abstract

Rapid word learning, where words are “fast mapped” onto new concepts, may help build vocabulary during childhood. Recent evidence has suggested that fast mapping might help rapidly integrate information into memory networks of the adult neocortex. The neural basis for this learning-by-fast mapping determines key properties of the learned information.

Keywords

fast mapping; learning; consolidation; memory; hippocampus

Learning from the environment

When one thinks about the processes governing word learning, one typically thinks of young children, who learn new words at a remarkable rate. Yet we learn new words and concepts throughout our lives: *Vape. Selfie. Fracking*. But, outside the classroom, we are rarely explicitly taught new words and concepts. Instead, we extract and learn information from a continuous flow of sensory input. In order to read this article, you have had to build a substantial vocabulary, much of which you learned in childhood.

The learning environment of children and adults often includes ambiguity, inference and context. A learning paradigm that mimics this situation has been named “fast mapping”[1] (Figure 1). We note that, perhaps unfortunately, this phrase has taken on several other meanings in the literature, including the process of rapid learning and the cognitive process of linking a name and concept, but we employ the paradigm usage here. In a common instantiation, fast mapping has three key characteristics, where the new word i) is encoded incidentally; ii) is introduced in context with an already-known item; iii) has a meaning that is apparent through inference (“disjunctive syllogism”, or process-of-elimination). Historically, fast mapping has predominantly been studied in young children, but recent

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attention has turned to adults, and how the learning paradigm might have significant neural and cognitive consequences.

A distinct neural pathway?

When we are explicitly taught information, the material is successfully learned and eventually consolidated through interactions between the hippocampus and regions of neocortex. At first, incoming information is rapidly encoded by the hippocampus, and following time and often sleep, is gradually consolidated into long-term memory in neocortex[2].

Curiously, at the developmental stage where children can rapidly learn words[3], the hippocampus is not yet fully developed, and furthermore, children with abnormal hippocampal development appear capable of learning new words at a typical rate. Results such as these raise the idea that fast mapping during childhood may not depend on the hippocampus. Recent findings have suggested the intriguing possibility that the fast mapping procedure may evoke a unique set of neural processes even in adulthood. We group key questions into two sets: i) whether learning through fast mapping operates independently of the hippocampus; ii) whether it accelerates the integration of new information into existing memory networks. First, can fast mapping enable learning that operates independently of the hippocampus? This possibility was first addressed in a study of amnesic patients with hippocampal damage. Despite their very impaired explicit learning, patients were able to learn names for unfamiliar fruits, vegetables, flowers and animals through fast mapping[4], as shown in a surprise recognition test 10 minutes, and then one week, after learning. Although prior studies have reported some semantic learning in amnesic patients, this usually requires extensive training, in contrast to the two trials of fast mapping that were sufficient here.

This report generated a flurry of interest in fast mapping in adulthood; however, the matter of whether fast mapping can ‘bypass’ the hippocampus is far from settled. A direct replication attempt with another group of hippocampal patients with more severe amnesia, has failed to find learning after fast mapping[5]. One additional study deviated from the first’s fast mapping paradigm in several ways (such as using a less elaborative task (clicking the new item) and introducing the study as a word learning investigation), which may explain the atypical pattern of recognition memory performance found, making the results difficult to interpret[6]. A later replication of the original study was successful[7]. In cases of milder hippocampal atrophy, through natural aging, fast mapping has not supported learning more than explicit encoding[8], although the high level of remaining hippocampal volume (88% of the younger participants’ volume) limits the implications for hippocampal dependence. An additional finding does, however, challenge the hippocampal-independence theory, as hippocampal volume in young and older adults predicted recognition performance after fast mapping (as well as after typical explicit learning)[8]. Direct comparisons of subjects with differing hippocampal integrities is not the only means to address the question of hippocampal involvement (or lack thereof) in fast mapping. Even in subjects with normal hippocampal functioning, a prediction that arises from computational models of memory is that hippocampally-bypassed information should not benefit from hippocampally-mediated resistance to interference. Consistent with this, it has been shown that information learned through fast mapping can be particularly susceptible to interference[7].

A second question is whether fast mapping can rapidly integrate new information into memory networks in the neocortex. Although this hypothesis arises from discussions of hippocampal-independence, it is a distinct matter, as rapid cortical consolidation could occur with or without hippocampal involvement. There is less patient evidence speaking to this point, although two patients with polar temporal cortex damage have shown impaired learning by fast mapping[4], as expected if fast mapped information is directly incorporated into this cortical area, which is linked to representing already-integrated known concepts[9]. At this stage, these results can only be tentative: the patients had concurrent medial temporal cortex damage, and were impaired at explicit encoding, limiting both anatomical and cognitive specificity.

What should cortex-consolidated information look like? Models of memory predict that, through consolidation, learned material becomes connected with existing knowledge. In recent experiments, we have found evidence that names for animals learned through fast mapping (but not explicit encoding) do have behavioral markers reflecting successful integration into lexical and semantic memory networks in cortex[10]. These response-time markers typically emerge days after learning, yet after fast mapping, they emerged just 10 minutes after training and continued to the next day. The day following training, fast mapped (but not explicitly encoded) words began to affect responses to semantically related items, suggesting integration into memory systems that represent meaning. This accelerated influence of newly learned words on existing long-term knowledge supports the theory that fast mapping accelerates the incorporation of new items into cortical memory systems.

Neural mechanisms

What neural mechanisms might underlie fast mapping's impact? One clue may come from another memory phenomenon that allows rapid learning: the effect of having a "schema" – a structure of existing related knowledge[11,12]. This existing structure allows new material to become learnt after very few presentations. The possible role of existing knowledge in fast mapping (through ruling-out a known item during the inference task) may draw on similar mechanisms[10].

We have also previously hypothesized that accessing the memory representation for the known item during the fast mapping task may activate the neuronal population underlying the new item[10]. Models of semantic memory suggest that similar items in knowledge are represented by partially shared 'units'[2]. The activation of neurons underlying the newly learned item, via the known item, may support rapid learning.

A further possibility is that the inference task during fast mapping leads to deeper (more elaborative) encoding. One challenge to this view is that adults rarely show superior declarative memory from fast mapping (without extensive training), and that presenting participants with the perceptual question (without a known item) does not produce certain fast mapping effects[10].

A notable aspect of the patient studies we discussed at the beginning of this paper is their conflicting results. It is currently unknown why differences emerge across these amnesia studies. Possible explanations include variations in the locations of damage (particularly medial temporal cortex), "yet-unknown aspects of how the test is given"[5], or variability in exactly how people engage with the fast mapping procedure. As the burgeoning interest in fast mapping continues, investigators will need to address such factors, which in turn may help clarify underlying mechanisms.

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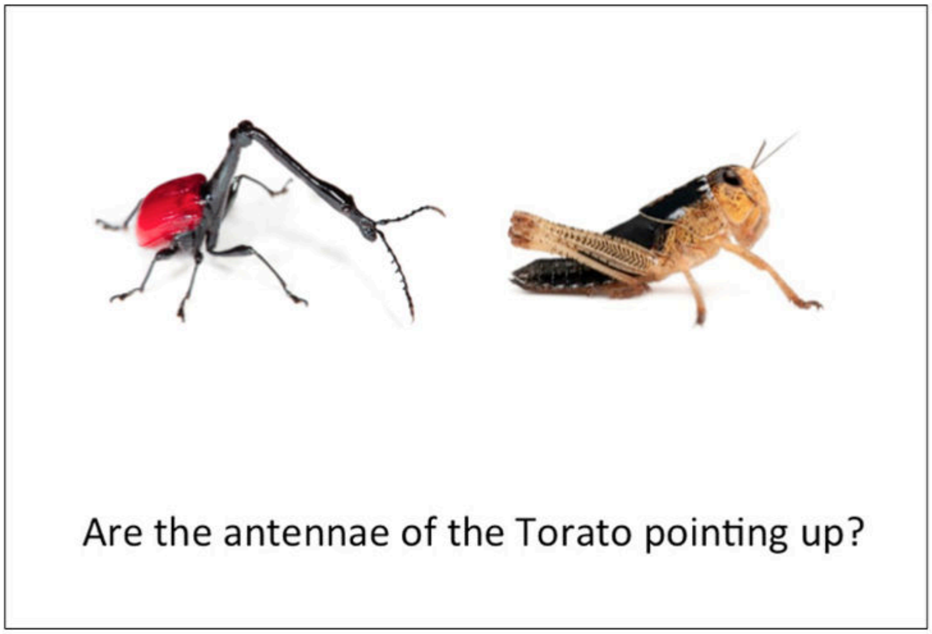

Figure 1. An example of a fast mapping paradigm

In this instance, the word “Torato” may be learnt as the name for the left insect (adapted from [10]). Note: In this example, the new name was constructed for experimental purposes (the insect is actually known as a giraffe weevil, shown with permission from the copyright holder; Alex Hyde; www.alexhydephotography.com). Other studies have employed the items’ real names.