



Variation across individuals and items determine learning outcomes from fast mapping



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ABSTRACT

An approach to learning words known as “fast mapping” has been linked to unique neurobiological and behavioral markers in adult humans, including rapid lexical integration. However, the mechanisms supporting fast mapping are still not known. In this study, we sought to help change this by examining factors that modulate learning outcomes. In 90 subjects, we systematically manipulated the typicality of the items used to support fast mapping (foils), and quantified learners’ inclination to employ semantic, episodic, and spatial memory through the Survey of Autobiographical Memory (SAM). We asked how these factors affect lexical competition and recognition performance, and then asked how foil typicality and lexical competition are related in an independent dataset. We find that both the typicality of fast mapping foils, and individual differences in how different memory systems are employed, influence lexical competition effects after fast mapping, but not after other learning approaches. Specifically, learning a word through fast mapping with an atypical foil led to lexical competition, while a typical foil led to lexical facilitation. This effect was particularly evident in individuals with a strong tendency to employ semantic memory. We further replicated the relationship between continuous foil atypicality and lexical competition in an independent dataset. These findings suggest that semantic properties of the foils that support fast mapping can influence the degree and nature of subsequent lexical integration. Further, the effects of foils differ based on an individual’s tendency to draw-on the semantic memory system.

1. Introduction

As we perceive and interact with the continuous stream of information in our environment, our brain is encoding, and occasionally consolidating, new knowledge. Although information can be presented explicitly, a learner must often extract it from its context. An approach that mimics the inferential manner in which we often encounter new words in our environment is “fast mapping”. In this procedure, a word for a new item is introduced alongside an already-known object, so that a person must infer a link between the new word and the item. Though first developed to model how young children learn new words (Carey and Bartlett, 1978), the learning paradigm has garnered interest over the last six years for its effects in adults (Coutanche and Thompson-Schill, 2014, 2015; Himmer et al., 2017; Sharon et al., 2011; Smith et al., 2014; Warren and Duff, 2014; Greve et al., 2014; Merhav et al., 2015). Several studies have reported hippocampal patients who could learn new words through fast mapping (but not through other approaches; Merhav et al., 2014; Sharon et al., 2011), leading to the suggestion that learning through fast mapping might bypass the hippocampus, and instead employ the anterior temporal lobe (Merhav

et al., 2015; Sharon et al., 2011). The nature of the phenomenon is currently under debate however, as several other investigations did not find a fast mapping effect in patients (Smith et al., 2014; Warren and Duff, 2014; also see Greve et al., 2014). More generally, there remains uncertainty over which conditions lead to successful fast mapping, and over its underlying mechanisms (Coutanche and Thompson-Schill, 2015).

Building on the suggestion that fast mapping might allow rapid cortical integration of new word knowledge, we previously observed that a behavioral signature for the integration of new words into the lexicon (lexical competition) becomes apparent very soon after fast mapping (Coutanche and Thompson-Schill, 2014). This contrasts with other learning paradigms, where competition emerges after a delay (Gaskell and Dumay, 2003; though also see Kapnoula and McMurray, 2015), due to the typically gradual process of consolidating new knowledge into cortex by the hippocampus (Davis and Gaskell, 2009). The idea of rapid cortical consolidation after fast mapping has been subsequently supported by several additional behavioral studies, which have found atypical interference (Merhav et al., 2014), and weakened consolidation via sleep (Himmer et al., 2017), for words that are

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learned through fast mapping.

In this study, we investigate two kinds of variation that we hypothesized could modulate learning through fast mapping: variation across individuals and across items. Understanding the moderators and boundary conditions of cognitive phenomena can give useful insights into underlying cognitive and neural mechanisms, and can also shed light on why prior fast mapping patient studies have produced mixed results.

The first kind of variation – across individuals – is based on recent work suggesting that people differ in the extent that they draw on episodic, semantic, and spatial memory systems in everyday life (Palombo et al., 2013). A validated self-report survey, the Survey of Autobiographical Memory (SAM), reliably quantifies an individual's trait bias for relying on memory types in everyday life (Palombo et al., 2013). An examination of individuals' intrinsic networks of brain connectivity has identified different patterns of connectivity for individuals with biases for different memory types (as measured through the SAM; Sheldon et al., 2016). Interestingly, the pattern of brain connectivity associated with strong biases toward semantic memory processing (based on high semantic SAM scores) closely resembles the pattern of brain activity that is associated with learning by fast mapping (Merhav et al., 2015). Both the semantic trait and fast mapping are associated with brain networks that include the right and left middle frontal gyrus, right cingulate gyrus, right inferior frontal gyrus, right superior temporal gyrus, right middle temporal gyrus, and right precentral gyrus (compare Table 2 in Merhav et al. (2015) with Table 2–4 in Sheldon et al. (2016)). This overlap raises the intriguing possibility that individuals high in the semantic trait might be more likely to show strong lexical integration through fast mapping. In contrast, both episodic and spatial memory have been more closely associated with the hippocampus (Maguire et al., 2000; Schinazi et al., 2013). Given the hypothesized reduced hippocampal involvement during learning by fast mapping, it is possible that one or both of these traits are negatively related to lexical integration through fast mapping.

The second kind of variation we will examine is at the item level. There has long been behavioral evidence that the typicality of an item's features can strongly influence recognition rates and other behavioral responses (Rosch, 1973; Rosch and Mervis, 1975). The prominent “family resemblance hypothesis” (Rosch and Mervis, 1975) considers highly ‘typical’ items within a category to be those items that share many features with other members of its category (such as having a tail, four legs, and fur for “dog”). Recently, neuropsychological and neuroimaging studies have shown that typicality strongly influences how different areas of cortex respond to an item. For example, Iordan and colleagues recently found that occipitotemporal neural responses to typical items are more similar to the overall neural response to a category, than are responses to atypical items (Iordan et al., 2016). Additionally, in patients with semantic dementia – a disorder affecting the anterior temporal lobe (Merhav et al., 2015; Sharon et al., 2011) – the processing of atypical items is particularly vulnerable to disruption (Rogers et al., 2015). For example, during delayed-copying tasks, patients tend to omit an item's unique features (such as a camel's hump), but keep features that are shared across its category (such as its four legs; Rogers et al., 2015). This evidence suggests that typicality plays a strong role in the neural organization of concepts, particularly in the anterior temporal lobes: a region that has been implicated as crucial for learning through fast mapping (Merhav et al., 2015; Sharon et al., 2011). Our knowledge of atypical (but not typical) items is particularly represented in this region (Patterson et al., 2006). For example, damage to the anterior temporal lobe disproportionately impairs items that have atypical colors for their category (Rogers et al., 2007). Findings such as this support a hypothesis that the anterior temporal lobes contain a semantic hub that is important for defining conceptual boundaries, and representing items at the boundaries' edge (i.e., atypical category members; Lambon Ralph et al., 2010; Mayberry et al., 2010). Thus, “to accept atypical targets and correctly reject pseudo-

typical foils, the ATL is a key substrate for counteracting superficial sensory similarity (which misleads responses) and extracting conceptual coherence” (Chiou and Lambon Ralph, 2016, p. 77).

Here, we examine the typicality of the foils that are used to successfully learn via fast mapping. In previous work, we found that the known item that accompanies a learned item in the fast mapping paradigm (the “supporting foil”) is critical for observing rapid lexical integration (Coutanche and Thompson-Schill, 2014). Specifically, we showed that a learning procedure with the same question (e.g., “Is the Torato's antennae pointed up?”), but without the known item to discount, did not create the same rapid lexical integration that we observed after fast mapping. Given the central role of the supporting foils, and evidence that the anterior temporal lobes underlie learning through fast mapping, we hypothesized that the foils' typicality might influence the size of the subsequent lexical competition effect (LCE) observed during retrieval. We therefore systematically manipulated whether the supporting foils had features that were typical or atypical for their taxonomic category, to examine if this influences the degree to which a learned item becomes incorporated into the lexical network. By examining this variation, and individual variation in memory traits, we test factors that might modulate lexical integration through fast mapping.

2. Materials and methods

2.1. Participants

Ninety participants (41 males; mean (M) age = 20.2, standard deviation (sd) = 2.5; English speakers without a learning or attentional disorder) were randomly assigned to one of three learning conditions: fast mapping (FM), explicit encoding, or implicit encoding. Participants were recruited until thirty were allocated to each group. Informed consent was obtained for each participant prior to beginning the study. Participants were compensated either through course credit or payment for their time. The University of Pittsburgh Institutional Review Board approved all procedures.

2.2. Design

2.2.1. Learned stimuli

Participants were shown images of sixteen unfamiliar animals (six mammals, two insects, four birds, four fish), selected based on (un)familiarity evaluations by an independent norming group. At the study's conclusion, participants were asked to rate on a scale of 1–7 how familiar they had been with each animal prior to beginning the study. Following the approach of our prior work (Coutanche and Thompson-Schill, 2014), data from trials involving an animal that had received a familiarity rating of four or higher for a specific participant were removed from analyses. Any participant that rated more than half the animals as previously familiar was not analyzed, and was replaced with a new participant (final familiarity rating: $M = 1.45$, $sd = 0.37$).

Participants learned six-letter words for each of the 16 unfamiliar animals (Table 1). These words were selected from a list of hermit words (i.e., words that do not become a new word by changing just one letter) from a previous study of lexical competition (Bowers, Davis, and Hanley, 2005; counterbalanced across participants; see original investigation for the procedure generating these words). Half the participants learned one set of 16 words (List 1 in Table 1), while the remaining participants learned another set (List 2 in Table 1). Words were randomly assigned to the unfamiliar animals.

2.2.2. Training procedure

The explicit encoding, FM, and implicit encoding conditions consisted of participants viewing the sixteen unfamiliar animals and responding to perceptual questions, following the procedures used in Coutanche and Thompson-Schill (2014; Fig. 1). Each animal was

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