How do properties of semantic memory influence the integration of new memories via Fast Mapping?

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Preface

Before you lies the master thesis 'How do properties of semantic memory influence the integration of new memories via Fast Mapping?'. This study was conducted as an experiment which researched the influence of semantic properties of new memories on the integration of new information via a word learning paradigm called Fast Mapping. This thesis was written as a graduate project for the master General Linguistics at the Radboud University in Nijmegen. I worked on this thesis from January 2021 until August 2021.

Together with my two thesis supervisors, dr. Clara Ekerdt and dr. James Cousins, I have created the research questions for this research. The answers to these research questions were found by conducting an experiment among Dutch native participants.

I would like to take this opportunity to thank my two supervisors, Clara and James, for the extensive guidance during the process of creating this experiment and writing this thesis. Working with you has sparked my love for doing research even more and triggered me to want to pursue academics even further. I would also like to thank dr. Guillén Fernández for allowing me to join the Memory and Emotion lab at the Donders Institute for Cognitive Neuroimaging and for your guidance. Further, I would like to thank dr. James McQueen for allowing me to join the Sound Learning lab at the Donders Centre for Cognition. I am very thankful for all the experience and knowledge that I have gained by working in both your labs as an intern.

Lastly, I would like to thank my parents, family and friends for facilitating and always supporting my academic career. And for supporting me while I pursue my career further by doing a second research master program in Linguistics and Communication Sciences.

I sincerely hope you enjoy reading this paper.

Rachelle Hamelink

Abstract

In adults, successful word learning depends on incorporating new knowledge into already existing memory networks. Recent studies have formed an updated view on the role of existing knowledge in rapid acquisition of new memories. An experimental word learning paradigm called Fast Mapping (FM) has shown evidence of rapid integration into long-term memory systems. Normally, this integration is a gradual and timely process, which often benefits from sleep. However, fast mapping is interesting because it has shown evidence for integration right after testing, rather than over a consolidation period. In this paradigm, participants learn the name of a new item whilst it is presented side by side with an item that is known to them (foil). This formed a hypothesis that this fast mapping paradigm could modulate a rapid acquisition response into semantic memory. This study tested this hypothesis by researching forty healthy native Dutch adults and comparing a fast mapping and an incidental encoding (IE) paradigm. Additionally, the semantic properties of the known items were manipulated to influence the effect of existing knowledge. We influenced this effect by using known items with many semantic associations (dense foils) or fewer associations (sparse foils). The hypotheses in this study were tested using a lexical integration task and a three-alternative forced choice recognition task. The present study showed no evidence for fast mapping to modulate rapid acquisition through lexical integration or recognition. Further, it showed no evidence for foils with a dense semantic neighborhood to cause a lexical integration effect or increase accuracy in the recognition task.

Key words

word learning – memory – fast mapping – lexical integration – incidental encoding – semantic neighborhood density – word associations

Introduction

Theoretical Framework

Sole memories do not exist. All experiences that occur exist in a prior strain of memories in our brain. This paper focuses on a paradigm for word learning called Fast Mapping (FM), which attempts to mimic the manner in which new experiences enter our memory system. The paradigm presents an unknown image, with a given name, next to a known image, triggering existing knowledge while incidentally learning new words. This paradigm has shown tentative evidence for the hypothesis that new knowledge, when presented next to existing knowledge, can lead to fast acquisition of new memories and transfer these new memories to long-term memory rapidly without benefiting from time and sleep factors (Coutanche and Thompson-Schill, 2014; Zaiser, Meyer and Bader, pre-print).

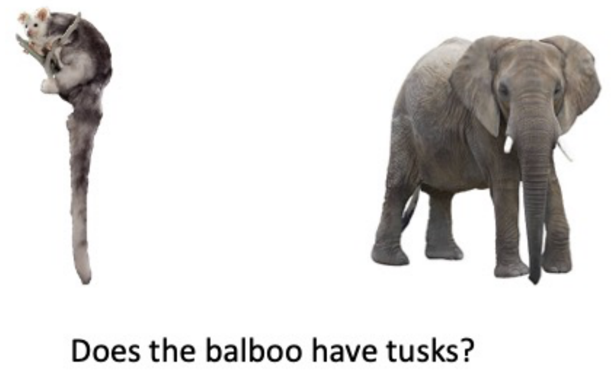
These fast mapping results were striking since, in neurobiology and psychology research, it is generally thought that new information enters the brain through a system of two deeply connected processes, which McClelland, McNaughton and O'Reilly (1995) theorized as the complementary learning systems framework. According to this framework, the brain has a neocortical and a hippocampal learning system. The initial hippocampal phase of fast acquisition is where new synaptic connections grow and existing synaptic connections restructure when new information is obtained. After this initial phase, the new memories go through the system consolidation phase, which restructures the existing memory support system to fit the new experiences into our existing knowledge. This system is called complementary due to the fast nature of the hippocampal phase and the slow nature of the hippocampal consolidation phase. (McClelland, McNaughton & O'Reilly, 1995; Norman & O'Reilly, 2003; Franklin & Bontempi, 2005). Memory consolidation can be defined as the process where recently learned experiences are transferred into long-term memory, through the earlier mentioned restructuring of already existing synaptic connections. Consolidation is theorized to benefit from time (Franklin & Bontempi, 2005) and sleep (Stickgold & Walker, 2005). After restructuring, memories are consolidated from an initial fragile state towards a stabile disruption-resistant state (Frankland & Bontempi, 2005).

Davis and Gaskell (2009) theorized that the acquisition and consolidation of both new memories and new words may have comparable underlying processes. Following the theory of the complementary learning system framework, this proposes that new words will similarly follow an initial hippocampal phase of fast acquisition and are then gradually consolidated into the long-term memory systems over time. (McClelland, McNaughton & O'Reilly, 1995) This theory was later shared by Tamminen and Gaskell (2013), who stated that word learning is similar to semantic memory as in that consolidation of new words is an equally gradual process that benefits from time and sleep factors. In word learning there are various methods to research consolidation. An example is a free recall measure, where participants are asked to recount as many learned words as possible. Another example is an associative recognition measure, where participants are asked to combine the learned words with the correct pictures. And the last example is a lexical competition measure. This task was first introduced by Bowers, Davis and Hanley (2006). In this task, researchers create pseudowords for picture-word pairs. The pseudowords are formed from hermit words (i.e., a word that has no orthographical or phonological neighbors in the language). These pseudowords are created by changing one character from the original hermit word, thus creating a new lexical neighbor for the original word (e.g., *bamboo* is changed into the created pseudoword *balboo).* These words are then matched with pictures that are unfamiliar to the participant. After training these words, the original hermits from which the pseudowords were derived are then used in a lexical decision task. Coutanche and Thompson-Schill (2014) showed evidence that suggest when a new word is successfully learned, it will cause slowed responses to the original hermit in a lexical integration task (e.g., slowed responses to '*bamboo'*) compared to responses to words that had no lexical neighbors in the word learning phase of the experiment. These slowed responses show an indication that the new learned pseudoword has been integrated into long-term memory. These results (Coutanche & Thompson-Schill, 2014) were found in a lexical decision task ten minutes after training. Usually, this effect is only found after an overnight consolidation period (Davis & Gaskell, 2009).

A study by Sharon et al. (2011), however, showed that patients with severe hippocampal damage that were unable to learn and retain new word-picture pairs in an explicit encoding condition, were able to learn and retain this new information for a week through a fast mapping condition. This is a paradigm used to teach participants words for objects. In a fast mapping trial, participants are presented with two pictures, of which one is of a familiar object/animal (e.g., an elephant) and the other is a picture of an unfamiliar object/animal (e.g., an Australian long-tailed less-known marsupial) (Figure 1). In order for a fast mapping trial to be successful, participants must be fully familiar with the presumed known object or animal and fully unfamiliar with the presumed unknown object or animal. While viewing both pictures, participants have to answer a question asking about a physical attribute of the unknown object/animal. Included in the question is the created pseudoword-label of the unknown object/animal (e.g., 'Does the *balboo* have tusks?'). To successfully answer the question, participants need to realize that the unknown word refers to the unfamiliar object in the question and respond regarding the visual properties of the picture (Sharon et al., 2011).

Figure 1.

An example of a fast mapping trial. The word 'balboo' is created from the hermit word 'bamboo' and refers to the animal on the left. In this example, the elephant on the right is the presumed known animal and the Australian long-tailed marsupial the presumed unknown animal.



In the comparing explicit encoding condition in the Sharon et al. (2011) study, participants were shown an unfamiliar picture and explicitly told to remember the given name to this picture. In this condition, they did not show the same retainment of new information (Figure 2).

Figure 2.

An example of an explicit encoding trial.

The learning and means of retaining information in the study by Sharon et al. (2011) were tested using a recognition task ten minutes and one week after initial training. This result is particularly striking given the importance of the initial hippocampal phase of the complementary learning systems framework and the lack of hippocampal support in the tested patients. These results rose questions about the specialty of the fast mapping paradigm that facilitates rapid acquisition of words. In the past decade, more studies have suggested evidence that the fast mapping can accelerate the normally slow process of memory consolidation, when certain conditions apply (Sharon, Moscovitch & Gilboa, 2011; Atir-Sharon, Gilboa, Hazan, Koilis & Manevitz, 2015; Merhav, Karni & Gilboa, 2015; Himmer, Müller, Gais & Schönauwer, 2017, see also Coutanche & Thompson-Schill, 2014; Coutanche & Koch, 2017).

The results by Sharon et al. (2011) led to a hypothesis that new information learned through a fast mapping paradigm circumvents the hippocampus completely. However, other studies have failed to replicate the findings by Sharon et al. (2011) (see: Greve, Cooper & Henson, 2014; Smith, Urgolites, Hopkins & Squire, 2014; Warren & Duff, 2014; Warren, Tranel & Duff, 2016). Greve, Cooper and Henson (2014) tested the hypothesis by Sharon et al. (2011) through extending the fast mapping paradigm to the concept of healthy aging. They compared older and young participants between an explicit encoding and fast mapping condition. Their results showed no evidence that the fast mapping paradigm alleviated the memory deficit of older participants. Furthermore, structural magnetic resonance imaging (MRI) scans showed reduced hippocampal grey matter in older participants, which correlated with the memory performance of the older participant group. Therefore, their study did not provide evidence for the proposed hypothesis by Sharon et al. (2011) that fast mapping will lead to circumvent the hippocampus. Warren and Duff (2014) attempted to replicate the initial findings by Sharon et al. (2011) through comparing severe and mildly amnesic patients with healthy comparison. Severe amnesic patients did not show evidence of learning after fast mapping and mildly amnesic patients only showed marginal learning. Their replication was deemed unsuccessful and they concluded that even though the hippocampus might not be essential for on-line fast mapping of new words, it is necessary for rapid learning of arbitrary relational information. The memory measure of lexical integration through fast mapping has previously shown evidence for a fast mapping effect in healthy adults. Coutanche and Thompson-Schill (2014) found a lexical competition effect in the fast mapping condition right after testing, compared to an explicit encoding condition (see also: Coutanche & Koch, 2017). This lexical competition effect was later replicated by Zaiser, Meyer and Bader (pre-print).

This rapid lexical competition effect may be caused by the role of prior knowledge that is activated through the presence of the known item in a classic fast mapping trial. An updated version of the complementary learning systems framework by Kumaran, Hassabis and McClelland suggests that prior knowledge can assist more rapid integration. Prior knowledge has a key role in a fast mapping paradigm, because of the role of the known item next to the unknown item. Supporting evidence for this theory was provided by Tse et al. (2007), who showed evidence that new information incorporated prior knowledge became independent of the hippocampus more rapidly. These studies may explain the importance of the known item that causes the fast mapping paradigm to allegedly circumvent the hippocampus and facilitate rapid acquisition. By showing the unknown item alongside a known item, this unknown item is directly presented alongside existing knowledge. The importance of existing knowledge lies in the synaptic connections that are created when new experiences enter the brain (McClelland, McNaughton & O'Reilly, 1995). In the revised research of the complementary learning systems framework by Kumaran, Hassabis and McClelland (2016), the role of existing knowledge was theorized to be the deciding factor in successful rapid acquisition. This emphasizes the importance of not only the presence of the unknown item, but rather the properties of this item and the accessibility of the unfamiliar item into the already known structures of the known item.

However, little is known about what the exact property of the known item is that modulates the fast mapping response. Coutanche and Koch (2017) manipulated the typicality of the known item in their experiment. Whilst undergoing a classic fast mapping trial (see Picture 2), participants answered questions about unknown animals, with the created label of the unknown animal in the question and the known items acting as a foil in each trial. The foils' typicality was manipulated per category, so that every foil acted as either a typical or atypical foil for the category (e.g., chicken served as a typical bird foil, penguin served as an atypical bird foil). A negative effect between typicality and lexical competition effect was found, so that if foils became more atypical, a greater lexical competition effect was found. The effect found was expected, due to the focus on unique features of atypical foils, in contrast to shared features between foil and target picture. These results suggest that the semantic properties of the known foil play an important role in modulating the fast mapping response. Secondly, Zaiser, Meyer and Bader (pre-print) manipulated the feature overlap between the unknown item and the foil. They created two conditions within the fast mapping paradigm, high feature overlap (i.e., where the unknown item and the foil share many features – e.g., both within category 'birds') and low feature overlap (i.e., where the unknown item and the foil share little features – e.g., an unknown bird presented next to a guinea pig). In this experiment, the researchers were able to replicate the lexical competition effect found by Coutanche and Thompson-Schill (2014). However, no effect of feature overlap was found between high overlap and low overlap trials. In a second experiment in the same paper, semantic integration was tested. In this analysis, it is presumed that if words are integrated properly, they will have the ability to semantically prime already known related words. This was first tested in fast mapping by Coutanche and Koch (2017), where only the fast mapping participant group showed evidence for semantic priming after one day of testing. In the semantic priming experiment by Zaiser, Meyer and Bader (pre-print), this semantic priming evidence was not found, however, they did show a difference with regards to feature overlap. The high overlap group showed a significantly larger semantic priming effect than the low overlap group. Therefore, the authors proposed that while feature overlap may not trigger slowed response times in a lexical decision task on the item-level, but it might influence semantic integration of newly learned word and picture-combinations. Lastly, Li, Hu and Yang (2020) manipulated the foil by first asking participants to name exemplars of different categories that were proposed to them. From this ranking, categories of pictures were created based on the quantity of exemplars that were named by participants in the preceding questionnaire of the experiment. The number of exemplars was used as a measure of prior knowledge, where the categories with the highest quantity of exemplars were used to create the familiar categories (e.g., vegetables). The categories with the least produced exemplars were used as unfamiliar categories in this experiment (e.g., Chinese medicine). The effect of prior knowledge was measured between a fast mapping and explicit encoding group, similarly to the Sharon et al. (2011) study. They found that a higher level of prior knowledge, here measured as a higher level of familiarity with the category, increased memory performance of word-picture associations. They found this effect in the fast mapping group ten minutes after testing, compared to the explicit encoding group, where this effect only showed up after one week of consolidation. In that way, these results also show evidence for the fast mapping paradigm response. These studies show the importance of the foil, but are inconsistent with regards to the properties of the foil that cause the specific response to the fast mapping paradigm. This was emphasized by Zaiser, Meyer and Bader (2019), that exact factors modulating the fast mapping response are still to be determined. The combined results of these studies suggest that the level of activated prior knowledge has an important role in modulating the fast mapping memory response. The study by Zaiser, Meyer and Bader (pre-print) additionally suggest that while on the item level, feature overlap may not cause a greater lexical integration effect, it might influence semantic integration of the new word.

In this study, we investigated the role of the properties of the foil further by manipulating semantic neighborhood density. This was tested with two groups, an incidental encoding (IE) and a fast mapping (FM) group. The design of the incidental encoding group was based on Coutanche and Thompson-Schill (2014). In this study, no differences in accuracy on the recognition memory measure were found between the incidental encoding and fast mapping group, thus forming a better comparable pair of groups. In an incidental encoding trial, the same question is asked as would be asked in a classic fast mapping trial, however, without the presence of the known foil (see Figure 3 below).

Figure 3.

An example of an incidental encoding trial.

Does the balboo have tusks?

Within the fast mapping group, we manipulated whether foils had a dense semantic neighborhood or a sparse semantic neighborhood. These neighborhoods were formed by researching the quantity of word associations per foil in a word association database (De Deyne, Navarro, Perfors, Brysbaert & Storms (2019). The foils with a largest quantity of word associations were selected as dense foils and the foils with the smallest quantity of word associations were selected as sparse foils. We hypothesize that a dense semantic neighborhood helps modulate the fast mapping response and thus results in slower responses to original hermits from targets that were depicted next to a dense foil in the lexical competition task compared to targets that were depicted next to a sparse foil. This hypothesis is based on Tse et al. (2007) and Kumaran, Hassabis and McClelland (2016) who found that a greater extent of prior knowledge modulates fast acquisition of new memories. Foils with a dense semantic neighborhood represent a greater quantity of present prior knowledge, since their associated network in the brain is larger than in foils with a sparse semantic neighborhood. With this larger quantity of prior knowledge, the new information enters into a larger network of existing knowledge, which is hypothesized to modulate rapid acquisition that may circumvent the hippocampus.

From the initial fast mapping study by Sharon et al. (2011), a hypothesis consisting of two components was formed regarding the fast mapping paradigm. First, that through a classic fast mapping paradigm, new information could circumvent the hippocampus completely and second, that the fast mapping paradigm modulates rapid acquisition, The second component of this hypothesis is tested in the present study. The first aim of this study is to replicate the lexical competition effect in the fast mapping group results shown directly after training by Coutanche and Thompson-Schill (2014) and Zaiser, Meyer and Bader (pre-print). The present study extends the use of this paradigm to the Dutch language so far done in English (e.g., Sharon et al., 2011; Coutanche & Thompson-Schill, 2014), German (Zaiser, Meyer & Bader, 2019) and Chinese (Li, Hu & Yang, 2020). The second aim of this study is to extend earlier manipulations of the foil to semantic neighborhood density. This is manipulated by quantifying the number of activated word associations per foil. We expect that a denser semantic neighborhood of the foil, will activate a larger network of existing knowledge, and this larger role of existing knowledge will increase accuracy in the recognition task and cause slowed responses in the lexical decision task, compared to targets presented next to a sparse foil.

Research Questions

This leads to the following research questions:

- To what extent does the Fast Mapping paradigm modulate rapid acquisition into long-term memory?
- To what extent does the semantic neighborhood density of the foil influence rapid integration?

Methodology

Participants

Fifty-seven participants in the range of 19-28 years (*M* = 23.16, *SD* = 2.33; 43 female, 13 male, 1 did not disclose; 53 right-handed, 4 left-handed) were initially tested for this study. After exclusion criteria were applied, forty participants were included in the final analyses in the age range of 19-27 (*M* = 23.10, *SD* = 2.23; 30 female, 9 male, 1 did not disclose; 36 right-handed, 4 left-handed). All parts of the study took place via Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine, Massonié, Flitton, Kirkham & Evershed, 2019). Data was collected between 30 July 2021 and 4 August 2021. Participants were able to complete the full experiment at home. Participants were healthy adults and native Dutch with no previously known learning disabilities or dyslexia. Informed consent was collected from all participants and all participants completed the experiment within approximately 35-45 minutes. They were compensated for their time with 8€. Participants were recruited via SONA, the participant recruitment system of Radboud University. The study was approved by the blanket approval of the CMO of the Donders Centre for Cognitive Neuroimaging, CMO2014/288. Participants were randomly assigned to the fast mapping or the incidental encoding group. Nineteen participants were assigned to the fast mapping group and twenty-one participants were assigned to the incidental encoding group. An independent samples *t*-test showed no significant difference in age between the fast mapping (*M* = 22.89, *SD* = 2.05) group and the incidental encoding (*M* = 23.29, *SD* = 2.41) group *t*(38) = .55, *p* = .586.

Design

The experiment followed a mixed 2x2 design with factors training group (fast mapping/incidental encoding) and semantic neighborhood density of the foil (dense/sparse). Training group was used as a between-subjects measure. Semantic neighborhood density of the foil was used as a within-subjects measure in the fast mapping group. Solely fast mapping participants were presented with a foil next to the target picture (see Figure 1). Associative recognition was measured using a three-alternative forced choice test and measured by accuracy in percentages. Lexical integration was measured using a lexical competition task and measured by differences in response times in msecs.

Materials and Design

The research design of this study is based on Coutanche and Thompson-Schill (2014) and Coutanche and Koch (2017). Participants were presented with thirty-two presumably unknown items or animals. In the initial phase of the experiment, from now on called the training phase, in the fast mapping group, the participant was presented with two pictures per trial (Figure 1). Underneath these pictures in the fast mapping group was a question, which refers to both depicted pictures and was answered by either yes or no. The placement of the target picture was counterbalanced among participants, as well as the key position of the yes and no answers on the screen. These unknown items or animals were selected as target pictures in eight different categories: flowers, fruits, insects, mammals, tools, reptiles, vegetables and musical instruments. These categories were based on designs by Coutanche and Thompson-Schill (2014); Zaiser, Meyer and Bader (pre-print) and Li, Hu and Yang (2020). In the training phase in the incidental encoding group, the participant was presented with only one picture of the unknown item or animal (Figure 2). Underneath this picture was the exact question as in the fast mapping group, which referred to only the target picture and was answered by either yes or no. The key position of the yes and no answers on the screen was counterbalanced among participants. At the end of the study, it was verified that the unknown items and animals were indeed unfamiliar to the participants, by asking whether they were able to name the items and animals. Then, they were asked to rate their familiarity with the items and animals on a 1-7 Likert scale. Any item or animal that was rated higher than three was removed from all tasks for that participant. If a participant rated more than half of the target animals and items above three, they were removed from final analyses. This resulted in the removal of eight participants, five from the incidental encoding group and three from the fast mapping group. The fast mapping (M = 1,75, SD = 1.32) and incidental encoding group (M = 1.89, SD = 1.40) showed no significant difference in prior familiarity with the targets $t(958) = 1.64$, $p = .102$. The target-pseudowords were created from Dutch hermit words, which are words that have no orthographical or phonological neighbor in their language. The pseudowords were created by changing one character of the hermit words and thus creating a new pseudoword that now has one neighbor in its language. All pseudowords were between 5-8 letters and pronounceable. A subset of pseudowords were taken from Bowers et al. (2005) and Zaiser, Mayer and Bader (pre-print). As not all hermit words from these studies were hermit words in Dutch, more pseudowords names were created based on hermit words chosen from the Cross-Linguistic Easy-Access Resource for Phonological and Orthographical Neighborhood Densities database (Marian et al., 2019). All newly created target-pseudowords were matched with one target picture, randomized but consistently paired across groups and participants, so that every picture would always have the same matched pseudoword. These target-pseudowords were counterbalanced across participants, to represent both a target word depicted next to a dense foil once and next to a sparse foil once.

The known items in the fast mapping trials act as a foil for the unknown target item. The foils were selected based on semantic neighborhood density. De Deyne et al. (2019) created a Dutch database called the Small World of Words. This database was created by giving participants a cue word and asking them to name three associations that came to mind when seeing a cue word (e.g., if the cue was 'cow', associations may be 'animal', 'milk', 'farm', etc.). These responses were then computed to a set of individual responses per cue. This led to a paired number of responses per cue. The number of responses per cue was calculated as the number of word associations per cue, which determines the density of the semantic neighborhood of a cue. A total set of sixty-four foils were created, since all target pictures are randomly shown twice, both with a different foil. These foils were selected within categories of the unknown target pictures, with sparse categories flowers and fruits. The dense categories consisted of insects, musical instruments and reptiles. Three categories consisted of both sparse and dense foils: mammals, tools and vegetables. Semantic neighborhood density was measured as the number of forward associations that were found per selected foil in the Small World of Words database (de Deyne et al., 2019). From these sixty-four foils, thirty-two had a sparse semantic neighborhood (*M* = 75.09, range = 61 – 83) and thirty-two had a dense semantic neighborhood *(M* = 108.53, range = 103 – 119). These foils were selected per category of the target and matched on frequency using the SUBTLEX database (Keuleers, Brysbeart & New, 2010) and on concreteness using the data of Brysbaert et al. (2014) (see Counterbalancing, Tables 1-6, all *p*'s > .05). One target picture was presented twice, both times with a foil from the same set of stimuli with equal semantic neighborhood density.

The foil pictures were selected based on the words from the previous calculations of the number of word associations per cue. No target word was paired with an unknown target picture that could lead to obvious manners of remembering the created word-picture combination. The target pictures were selected based on their unfamiliarity. For a fast mapping experiment, the target picture must be an unknown item to the participant, to ensure picture-word pair learning. A pre-test with a separate group of participants was performed to check the familiarity of the used targets, to ensure the unfamiliarity of the target. Participants of the study were also asked how familiar they were with the presented targets after testing on a 1-7 Likert scale *(not at all familiar – extremely familiar)* and were removed from the experiment if they showed higher familiarity scores (*define high scores after testing)* with the presented newly-learned items. Pre-testing was repeated until the set of target pictures consisted of no objects or animals that any participant of the pretest was able to name or had indicated familiarity levels for above three.

Procedure

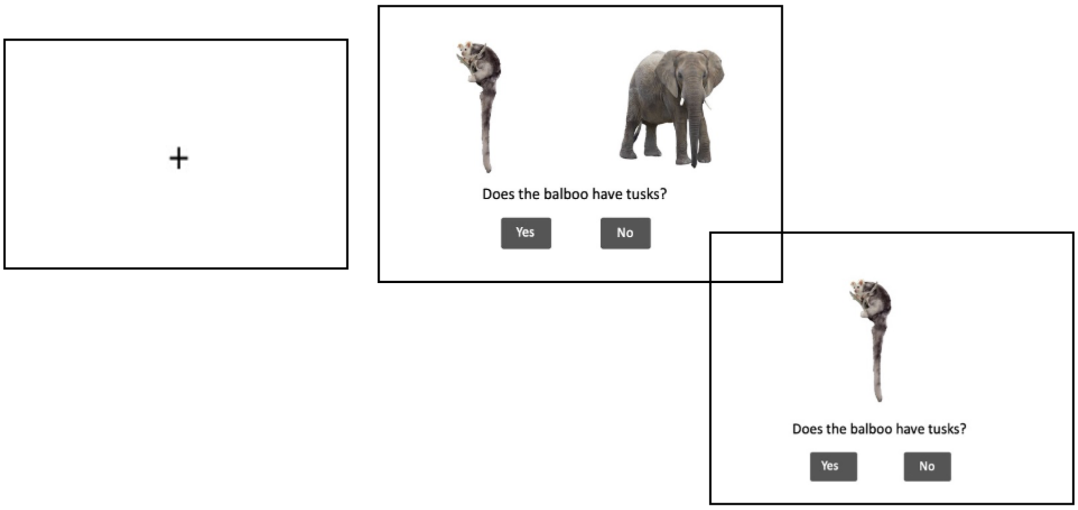
Both groups started in the training phase and trained with thirty-two targets. After the training phase, participant underwent an unrelated matchstick arithmetic task (Knoblich, Ohlsson, Haider & Rhenius, 1999) to prevent verbal rehearsal in the testing phase. This task was set to ten minutes and any participant who exceeded the fifteen minute mark on this arithmetic task was excluded in the final analysis. This resulted in the removal of five participants. After this, participants moved on to the testing phase consisting of a lexical competition task and a declarative memory task, in the form of a three-way alternate forced choice task. Both groups performed the same tasks in the testing phase, this ensured that any differences in results occur due to the differences in the training phase. After testing, participants were asked to rate their familiarity with the target pictures in a questionnaire. They were asked whether they were able to name then and to rate their familiarity with the pictures on a Likert scale from 1-7 (*not at all familiar – extremely familiar).* Afterwards, they were asked if they had any observations about the labels used in the experiment. Furthermore, they were asked if they had used any particular memorization strategies in the training phase of the experiment. After these questionnaires, participants were debriefed and informed that the labels used in the experiment were not the real names of the animals and objects, but created by the researchers. They were then thanked for their participation.

Training

Participants in the incidental encoding group were presented with the target pictures and a question about a feature in this target picture, e.g., “Is the tail of the balboe pointing down?”. The ‘balboe’ is the target-pseudoword for the unknown target picture shown. Target pictures and texts were shown for six seconds. During that time the participants were also required to answer the question shown on the screen, by using yes and no answer buttons. Between each trial, a fixation screen was shown for 1000 ms. Regardless of reaction times per question, the trial consistently remained on the screen for 6000 ms.

Figure 4.

A figure of a fixation cross and a fast mapping and an incidental encoding trial. Participants either viewed fast mapping or incidental encoding trials in the training phase.



The order of trials was randomized. After seeing all the thirty-two target picture-word pairs, these were shown again to the participants in a new random order. Participants in the fast mapping group went through a typical fast mapping paradigm. Every newly learned target was presented with a foil from the same category and an equal question as in the incidental encoding condition accompanying the two pictures (e.g., “Is the tail of the balboe pointing down?”). The question asked about an aspect of the picture that is present in both the target and the foil, and participants indicated their answer (yes/no) via button press. Each pair of pictures with the accompanying question was presented for six seconds in a random order. After seeing all thirty-two target pictures in a pair, the participants saw all the target pictures with foils again in a new random order. In the second run, the targets were paired with different foils based on Coutanche & Thompson-Schill, 2014). Participants that scored less than 70% accuracy in the training phase were removed from the final analyses. This resulted in the removal of five participants, four from the fast mapping group and one from the incidental encoding group.

Matchstick arithmetic task

Participants were presented with an unrelated matchstick arithmetic task (Knoblich, Ohlsson, Haider and Rhenius, 1999) that ensured no presence of verbal rehearsal. In this arithmetic task, participants were presented with equations of matchsticks that needed completion by altering one matchstick on either side of the equation, into a symbol or a Roman number. This test was done in a ten-minute window between the training and the testing phase. After ten minutes, the participants were able to continue to the testing phase.

Testing

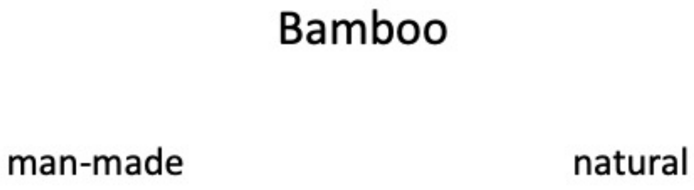
Both the fast mapping and incidental groups completed the same test tasks to assess learning of the new word-picture labels. Tests were presented in a fixed order (as presented below) and on the same day as learning, ten minutes after the training phase.

Testing - Lexical Integration

The lexical competition task consisted of the thirty-two original hermits that were used to create the target-pseudowords, thirty-two unused hermits and sixty-four filler words.

Figure 5.

An example of a lexical competition task trial.



Participants indicated whether the presented word is manmade or natural. Participants were encouraged to answer as quickly and accurately as possible by pressing the S and K buttons on their keyboard. Positions of the manmade and natural buttons were counterbalanced among participants. Each trial consisted of an 800 ms fixation cross, followed by a blank screen for 350 ms, a word for 500 ms and feedback (Correct or Incorrect), following the procedure by Coutanche and Thompson-Schill (2014). If participants did not answer in time, ‘Answer faster please’ appeared on the screen as encouragement for faster response times. Reaction times faster than 300 ms and slower than 1500 ms were removed from final analyses. No participants performed below 70% accuracy on the lexical integration trials. Lexical integration was operationalized as the mean difference in reaction times between used and unused created non-hermit words.

Testing - Declarative Memory

A three-alternative forced choice task was conducted to measure associative memory performance from the target-pseudoword and picture pairs trained in the training phase. Participants were presented with three pictures that they learned in the target phase, accompanied by a word in the middle which they learned in the target phase. Participants needed to indicate which picture belonged to the word in the middle, clicking the correct picture with a mouse. Before each trial, a fixation cross was shown for 1500ms and each trial was pictured for a maximum of 3000 ms. The trial continued to a new fixation cross as soon as the trial was answered.

Figure 6.

An example of a three-alternative forced choice task trial.

Debrief

After testing participants were asked to fill out a questionnaire with familiarity questions. They were asked to rate the targets based on how familiar they were with the target animals and objects before starting the experiment. This was done on a 7-point Likert scale *(not at all familiar – extremely familiar)*. Afterwards, participants were asked if they had noticed anything about the presented newly learned fictional names, e.g., whether they observed that these words differed one character from words that they might be familiar with in their own language. Lastly, participants were debriefed and informed that the given labels were created by the researchers.

Data Analysis

All *t*-tests to compare accuracy in the three-alternative forced choice task and the *t*-tests to compare average reaction times were two-tailed and the significance level was set to $\alpha = .05$. All data was collected through the Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine et al., 2019) and analyzed using IBM Corp SPSS Statistics Version 27.0 (IBM Corp, 2020) and RStudio (RStudio Team, 2020).

Counterbalancing Tables

In the lexical decision task, participants had to indicate whether a presented words was of manmade or natural origin. Words were presented across three different categories: no longer-hermit words (e.g., words that were used to create the labels of the unknown objects/animals), unused hermit words (e.g., words that were used in the lexical decision task but not used to created labels for the unknown objects/animals) and filler words (e.g., not hermits). These were matched on frequency using the SUBTLEX database (Keuleers, Brysbeart & New, 2010) and on concreteness using the data of Brysbaert et al. (2014). A one-way analysis of variance showed no significant effect of frequency on word group (*target/baseline/filler)* (F (2, 125) <1. A one-way analysis of variance showed no significant effect of concreteness on word group (*target/baseline/filler)* (F (2, 125) = 1.63, p = .200. A one-way analysis of variance showed no significant effect of frequency on word origin (*manmade/natural)* (F (1,126) <1. A one-way analysis of variance showed no significant effect of concreteness on word origin (*manmade/natural)* (F (1, 126) <1.

Table 1.

Reports of independent samples t-tests within word group between word origin with regard to frequency. p's all >.05.

		Group differences in frequency		*t*	df	*p*
		Mean	SD			
Target words	Manmade	3.61	.54	.56	30	.577
	Natural	3.74	.66			
Baseline words	Manmade	3.68	.62	.92	30	.367
	Natural	3.51	.35			
Filler words	Manmade	3.69	.50	.76	62	.450
	Natural	3.59	.50			

Table 2.

Reports of independent samples t-tests within word group between word origin with regard to concreteness. p's all >.05.

		Group differences in concreteness		*t*	df	*p*
		Mean	SD			
Target words	Manmade	4.51	.33	1.28	25.22	.211
	Natural	4.31	.53			
Baseline words	Manmade	4.30	.57	1.16	30	.254
	Natural	4.56	.73			
Filler words	Manmade	4.55	.24	.37	62	.714
	Natural	4.57	.27			

Table 3.

Reports of independent samples t-tests within foils between semantic neighborhood density group with regard to frequency. p's all >.05.

	Group differences in frequency		*t*	df	*p*
	Mean	SD			
Dense foils	3.54	.72	1.12	62	.268
Sparse foils	3.34	.69			

Table 4.

Reports of independent samples t-tests within foils between semantic neighborhood density group with regard to concreteness. p's all >.05.

	Group differences in concreteness		*t*	df	*p*
	Mean	SD			
Dense foils	4.82	.15	1.18	45.52	.074
Sparse foils	4.88	.81			

Table 5.

Reports of independent samples t-tests within word origin between semantic neighborhood density foil group with regard to frequency. p's all >.05

		Group differences in frequency		*t*	df	*p*
		Mean	SD			
Manmade words	Dense foil	3.64	.56	.18	14	.860
	Sparse foil	3.59	.55			
Natural words	Dense foil	3.78	.69	.25	14	.805
	Sparse foil	3.69	.66			

Table 6.

Reports of independent samples t-tests within word origin between semantic neighborhood density foil group with regard to concreteness. p's all >.05.

		Group differences in concreteness		*t*	df	*p*
		Mean	SD			
Manmade words	Dense foil	4.50	.47	.34	14	.739
	Sparse foil	4.43	.37			
Natural words	Dense foil	4.17	.61	1.10	14	.280
	Sparse foil	4.63	.43			

Results

Lexical Integration

An independent samples *t*-test between participant groups showed no evidence of slowed response times to words that lexically neighbor the trained words (compared to unused hermits) between the fast mapping group (*M* = 38.29, *SD* = 56.73) and the incidental encoding group (*M* = 14.01, *SD* = 52.11), *t*(38) = 1.41, *p* = .166. A paired samples *t*-test showed no evidence of slowed response times in milliseconds (compared to unused hermits) to targets that were trained next to a dense foil (*M* = 40.32, *SD* = 58.86) and targets that were trained next to a sparse foil *(M* = 33.29, *SD* = 65.91), *t*(18) = .56, *p* = .582 in the fast mapping group. These results show no evidence for the fast mapping paradigm to modulate rapid acquisition through slowed response times to lexical neighbors of earlier trained words. Further, no evidence was found that targets trained next to dense foil cause slower response times to original hermits than targets trained next to a sparse foil.

Figure 7.

Lexical integration task difference in response times between original hermits used to create the target-pseudowords and unused hermits, comparing the fast mapping and incidental encoding group. In the lexical integration task, participants were presented with the original hermits from the target-pseudowords from the training phase. They had to indicate whether these words were from manmade or natural origin. Error bars indicate standard error.

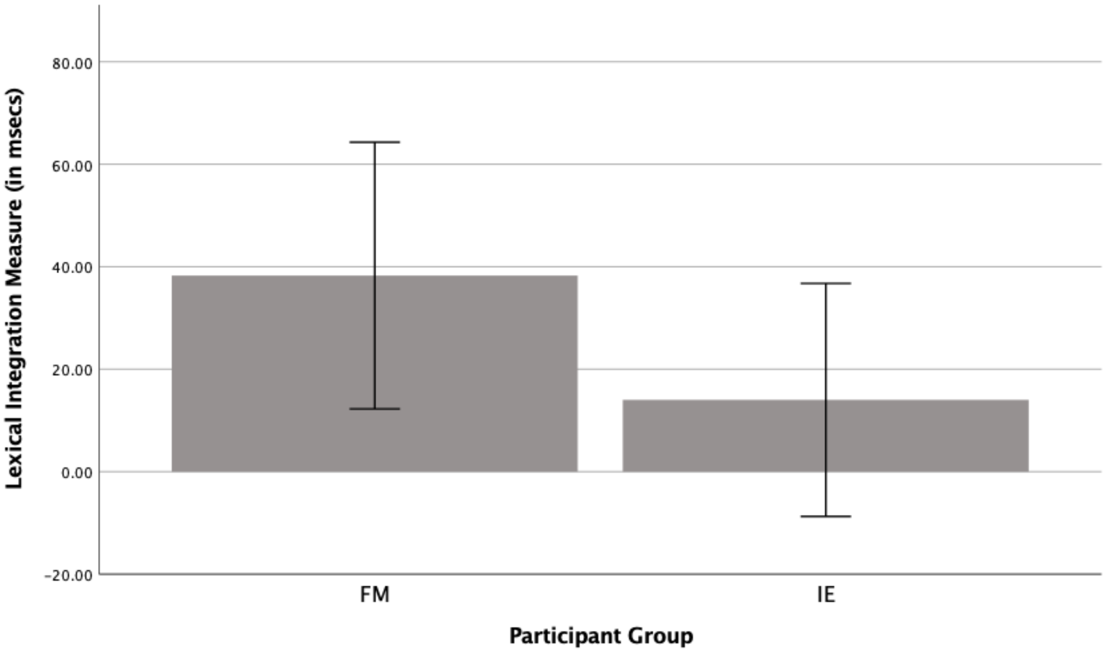


Figure 8.

Lexical integration task difference in response times between original hermits used to create the target-pseudowords that were trained next to a dense foil and unused hermits, within the fast mapping group. Error bars indicate standard error.

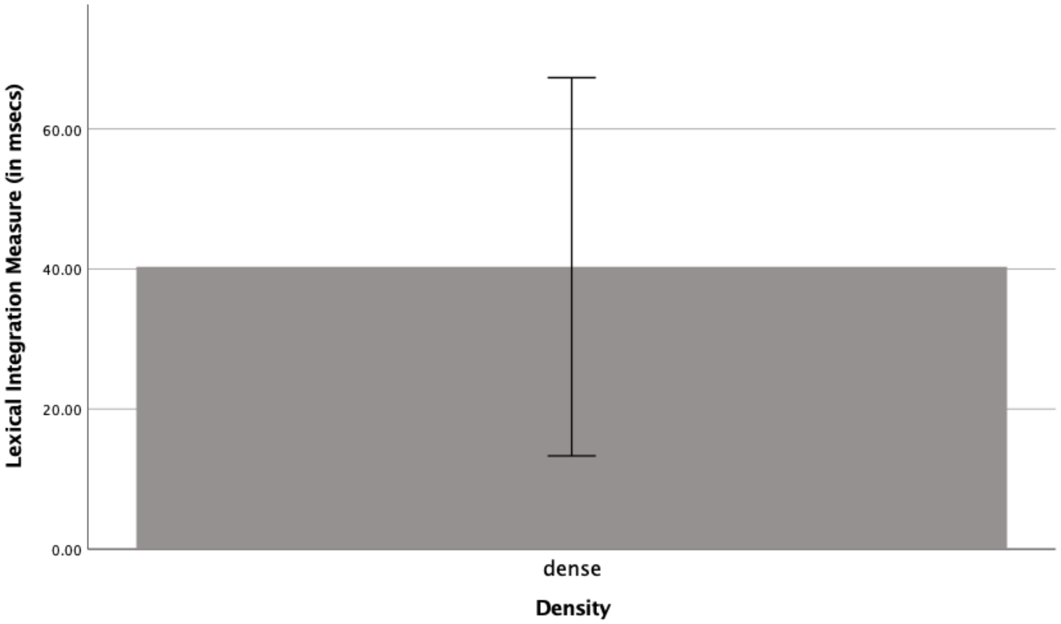
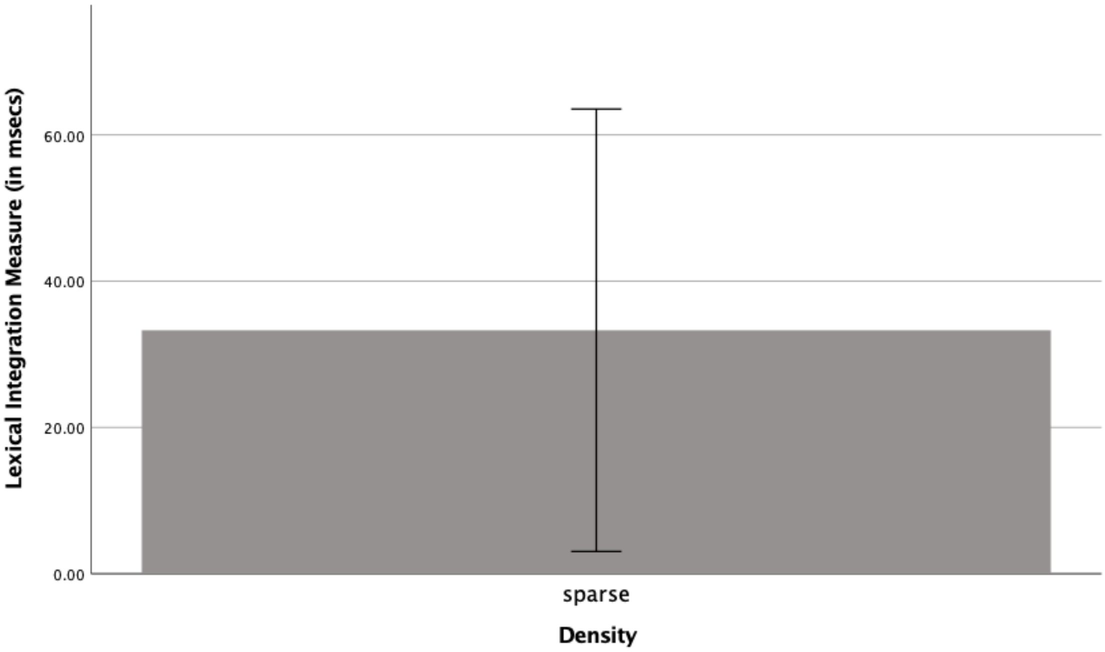


Figure 9.

Lexical integration task difference in response times between original hermits used to create the target-pseudowords that were trained next to a sparse foil and unused hermits, within the fast mapping group. Error bars indicate standard error.



Recognition Task

An independent samples *t*-test did not show a significant difference in accuracy between the fast mapping group (*M* = 45.40%, *SD* = 14.40%) and the incidental encoding group (*M* = 40.06%, *SD* = 16.38%), *t*(38) = 1.10, *p* = .280. A paired samples *t*-test showed no significant difference in accuracy between targets trained next to a dense foil (*M* = 45.29%, *SD* = 14.90%) and target trained next to a sparse foil (*M* = 45.51%, *SD* = 17.37%) within the fast mapping group, *t*(19) = .07, *p* = .948. These results show no evidence for a difference in accuracy between participants that were trained through the fast mapping phase and participants that underwent the incidental encoding phase. Further, no evidence was found that targets trained next to a dense foil caused higher levels of accuracy compared to targets trained next to a sparse foil.

Figure 10.

Recognition task results for the fast mapping and incidental encoding group. In the three-alternative forced choice task, participants were presented with a trained word and three trained pictures (one correct and two foils). Chance was set at 33%. FM = Fast mapping, IE = Incidental encoding. Error bars indicate standard error.

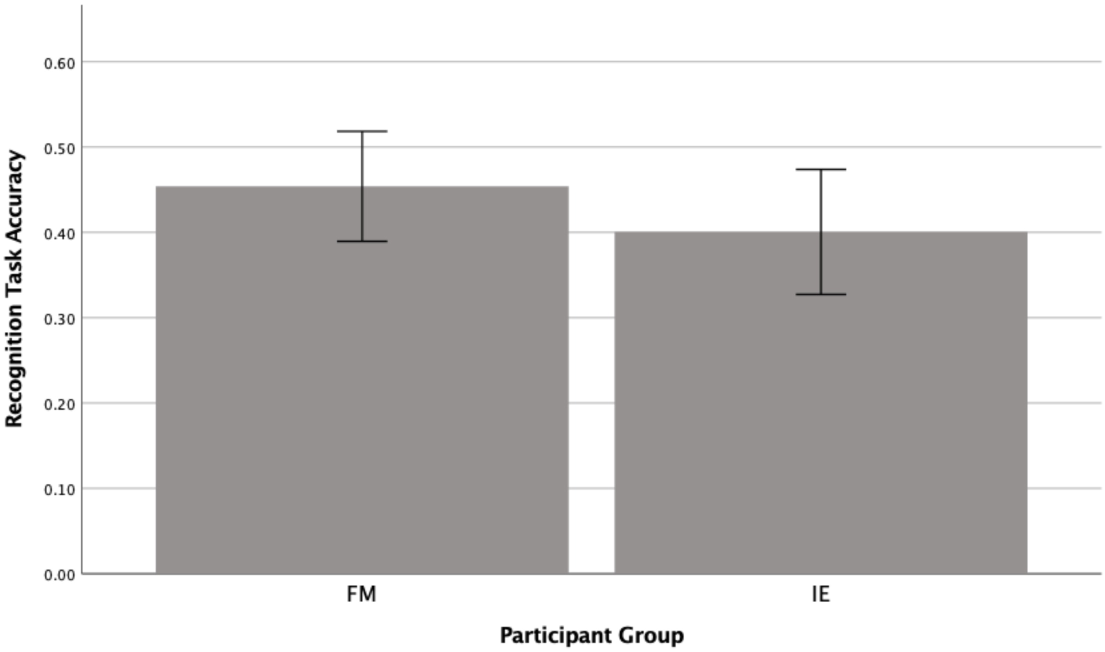
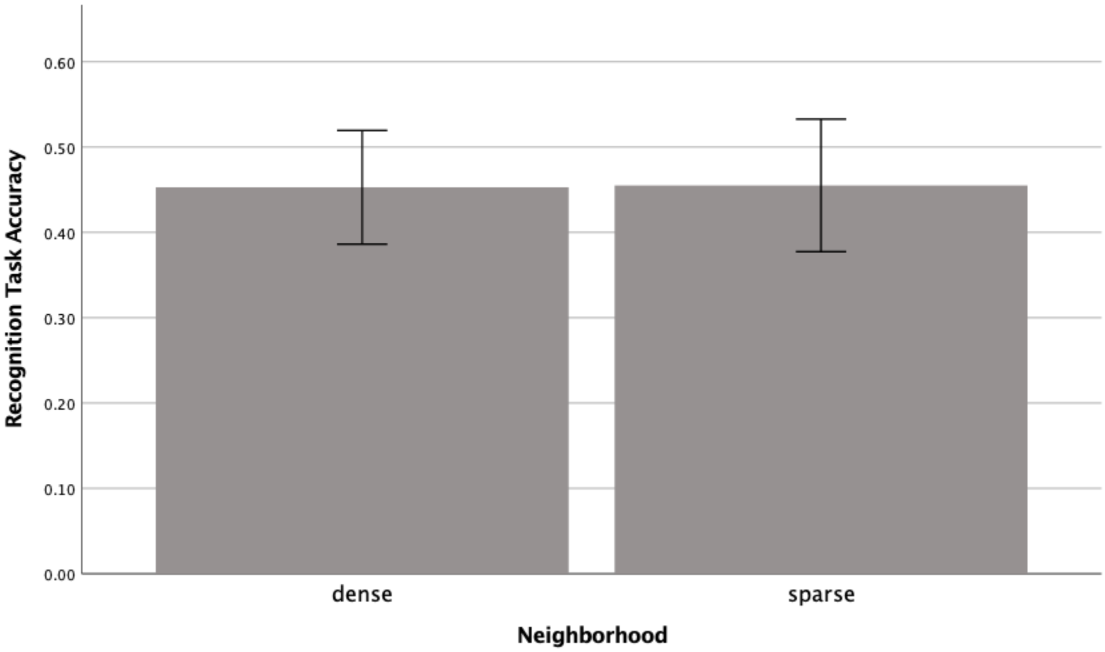


Figure 11.

Recognition task results within the fast mapping group, between the trained words depicted next to either a dense or sparse foil. Error bars indicate standard error.



Observation Questions

Out of forty included participants, nine participants answered when asked whether they had noticed anything in particular about the words in the training phase, that they had noticed that they were existing words that had one character changed. Five participants were not equally specific, however, they mentioned that the words were created words rather than real words. One participant explicitly mentioned that since they were aware of the known foil, they inferred that the target-pseudoword in the question referred to the other picture present, which was the target picture.

Discussion

The first hypothesis tested in this study researched whether fast mapping modulates rapid acquisition of new words. The findings in this study failed to replicate the lexical competition effect found directly after training by Coutanche and Thompson-Schill (2014) and Zaiser, Meyer and Bader (pre-print). No evidence for the fast mapping paradigm to modulate rapid acquisition through slowed response times to lexical neighbors of earlier trained words was found. Furthermore, we hypothesized that a dense semantic neighborhood of the foil would help modulate the fast mapping response. It was expected that longer response times would be shown for no longer-hermits from which the target-pseudoword was trained next to a dense foil compared to next to a sparse foil. This study did not show evidence for semantic neighborhood density as a means of modulating a fast mapping response. Further, we hypothesized that no significant differences in accuracy in the recognition task would be found, which was shown in the results. The fast mapping and incidental encoding group did not differ in accuracy in the three-alternative forced choice recognition task. Lastly, we hypothesized that a greater semantic neighborhood density would enhance the fast mapping effect within the recognition task. No evidence for this hypothesis was found, therefore this study has not provided evidence that the semantic neighborhood density of the foil influences the fast mapping response.

The lack of replication of the results by Coutanche and Thompson-Schill (2014) and Zaiser, Meyer and Bader (pre-print), among other failed replications in showing the fast mapping response (Greve, Cooper & Henson, 2014; Smith, Urgolites, Hopkins & Squire, 2014; Warren & Duff, 2014; Warren, Tranel & Duff, 2016), may show that fast mapping does not modulate rapid acquisition into long-term memory in healthy adults. Even though participants were able to retain information above chance levels (33%) in the three-alternative forced choice recognition task, their accuracy levels did not differ from participants who were trained in the incidental encoding condition. This may be seen as evidence that any form of incidental learning will show the same response when undergoing the lexical decision task and recognition task in this study. Furthermore, an earlier explanation by Zaiser, Meyer and Bader (pre-print) for the lack of replication in later studies might have also influenced the present study. They proposed that similarity between unknown and known items in the study might have influenced results. In the present study, targets and foils were selected within the same category. This may have limited the amount of existing knowledge that could have been activated by using targets and foils from different categories. If different categories were used, then a larger neural network of existing knowledge would have been activated, which could have resulted in a different outcome. Tse et al. (2007) emphasized the importance of prior knowledge for new information to possibly transfer to long-term memory systems with a shorter initial consolidation phase. Similarly, Kumaran, Hassabis and McClelland (2016) emphasized the importance of existing knowledge in the rapid acquisition of new memories through the updated complementary learning systems framework. Potentially, semantic neighborhood density could still influence the fast mapping response if this was applied across categories, by activating an even larger word associations network than was activated in the present study by manipulating dense foils. Lastly, different results may have been found if a semantic priming task was included in the present study. Coutanche and Koch (2017) showed evidence for semantic priming after one day of testing and while Zaiser, Meyer and Bader (pre-print) did not replicate these findings, they were able to show evidence with regards to feature overlap. Higher feature overlap showed significantly larger priming effects than low feature overlap. These results may be extended when manipulating semantic neighborhood density as done in the present study, by showing larger semantic priming effects for targets depicted next to a foil with a dense semantic neighborhood compared to targets depicted next to a foil with a sparse semantic neighborhood.

The study has several limitations. A bigger sample size could have altered the results, as Coutanche and Thompson-Schill (2014) included a total of fifty participants rather than forty. This study showed quite a high exclusion rate of participants, which could have been caused by the nature of conducting the experiment online on participants' personal laptops or computers, rather than in a supervised laboratory situation. Additionally, this may have caused interference in participants' internet connection and this may have showed in the response times (Anwyl-Irvine, Massonié, Flitton, Kirkham & Evershed, pre-print). As participants were not monitored as in laboratory conditions, it was not possible to ensure that participants were not distracted while performing the tasks in the experiment. Participants were asked to close all other open windows and tabs on their computer and perform the experiment in one sitting, but there was no manner of controlling this factor. Furthermore, this experiment doubled the number of targets that were trained in the training phase and thus the also doubled number of words used in the lexical integration task and the number of trials in the recognition task trials, compared to Coutanche and Thompson-Schill (2014). The length of this experiment may have caused fatigue as well as interference during coding due to the increased number of trials tested in the experiment. Zaiser, Meyer and Bader (pre-print) mentioned this limitation, as they included ninety-two trials in the encoding phase and were unable to replicate the results for the lexical integration results shown by Coutanche and Thompson-Schill (2014). Thus, a smaller number of trials, 16-24, as used by Coutanche and Thompson-Schill (2014) (see also: Greve et al., 2014; Sharon et al., 2011) may be a more fit number for the encoding phase. It needs to be noted, however, that Zaiser, Meyer and Bader (pre-print) used ninety-two encoding trails in their experiment and were able to show evidence for rapid integration through a fast mapping training phase. This indicates that further research needs to be conducted in order to create a standardized number of encoding trials for a fast mapping paradigm. This increase in trials can also have led to less homogeneity in the targets and foils presented to the participants. In the present study eight different categories for targets and foils were used, where e.g., Coutanche and Thompson-Schill (2014), Sharon et al. (2011), Coutanche and Koch (2014) used only animals in their research. Lastly, in the present study only visual questions were presented to the participants, rather than both visually and orally in e.g., Sharon et al. (2014) (see also: Greve et al., 2014; Merhav et al., 2014; Smith et al., 2014).

In future work, including a semantic priming task in the design of the present study, as per example by Coutanche and Koch (2017) might prove important nuances in the fast mapping response. Even though the present study did not find evidence for semantic neighborhood density to modulate a fast mapping response in a lexical integration task, they could be shown in a semantic priming task, similarly to the semantic priming results for high feature overlap by Zaiser, Meyer and Bader (pre-print). Another suggestion would be to extend the semantic neighborhood density condition across categories, rather than within category. This would mean not creating target categories based on their semantic neighborhood density, but selecting foils with very distinct sparse and dense neighborhood and then finding targets to match these foils to create the questions for the training phase. This could cause larger existing knowledge to be activated, which may cause new information to circumvent the hippocampus and modulate a rapid acquisition response through fast mapping. Finally, the last suggestion would be to include the semantic neighborhood density of the original hermits used to create the target-pseudowords for the training phase of the experiment. By including this number, a more thorough representation of the activated neural network during training, besides the foil, can be measured.

In conclusion, the present study has not provided further evidence that fast mapping modulates rapid acquisition into long-term memory. This adds to the already consisting controversy and uncertainties regarding the fast mapping response. Further replication is needed to investigate further whether the fast mapping paradigm can modulate rapid acquisition. Additionally, no evidence was provided that semantic neighborhood density can help modulate rapid acquisition or increase accuracy in associative memory. Therefore, the exact factors that determine the importance of the foil in a fast mapping paradigm, as first questioned by Zaiser, Meyer and Bader (2019) still remain uncertain.

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Appendix A

Table 7.

Newly created target words to Dutch hermit words, used as labels in order to evoke lexical competition.

Neighbor	Hermit	Translation
Friluur	Frituur	Fryer
Balboe	Bamboe	Bamboo
Pigaar	Pilaar	Pillar
Teltiel	Textiel	Textile
Servot	Servet	Napkin
Fakriek	Fabriek	Factory
Talijt	Tapijt	Rug
Kaltine	Casino	Canteen
Pateis	Paleis	Palace
Caruchon	Capuchon	Hood
Sarelliet	Satelliet	Satellite
Pataplu	Paraplu	Umbrella
Vulhaan	Vulkaan	Volcano
Setam	Sesam	Sesame
Herbenen	Hersenen	Brain
Kaspeel	Kasteel	Castle
Casano	Casino	Casino
Kalpoen	Kalkoen	Turkey
Rihier	Rivier	River
Plageet	Planeet	Planet
Woeltijn	Woestijn	Desert
Larune	Lagune	Lagoon
Oreaan	Oceaan	Ocean
Wamrus	Walrus	Walrus
Moeros	Moeras	Swamp
Paregaai	Papegaai	Parrot
Balterie	Bacterie	Bacteria

Kimeet	Komeet	Comet
Patasiet	Parasiet	Parasite
Tolpedo	Torpedo	Torpedo
Kalonder	Kalender	Calender
Gormijn	Gordijn	Curtain