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High Feature Overlap and Incidental Encoding Drive Rapid Semantic Integration in the Fast Mapping Paradigm

Ann-Kathrin Zaiser[1, 2], Patric Meyer[2, 3], and Regine Bader[1]

[1] Experimental Neuropsychology Unit, Department of Psychology, Saarland University

[2] Department of Applied Psychology, SRH University Heidelberg

[3] Network Aging Research (NAR), Heidelberg University

Contrary to traditional theories, it has been shown that novel, arbitrary associations can be rapidly integrated into cortical networks through a learning paradigm called *fast mapping* (FM), possibly bypassing time-consuming hippocampal-neocortical consolidation processes. In the FM paradigm, an unknown item is presented next to a known item and participants answer a question referring to an unfamiliar label, presumably inferring that the label belongs to the unknown item. However, factors driving rapid cortical integration through FM are still under debate. The FM task requires the discrimination between complex objects and the binding of the unknown item to the label. Discriminating between complex and especially highly similar objects is a central function of the perirhinal cortex, a structure also involved in the binding of single elements to a unit. We suggested that triggering perirhinal processing by increasing the demands on item discrimination through increasing feature overlap between the unknown and the known item might foster the binding of the unknown item to the label and their rapid cortical integration. We found lexical integration of the labels after learning through FM, but this was not affected by feature overlap. However, semantic integration of the label immediately after FM encoding was more successful when the items shared many features than when they shared few features. Moreover, effects of rapid semantic integration through FM were reduced if encoding was intentional and if no discrimination was required. This indicates that incidental encoding and a high feature overlap are driving factors for rapid semantic integration through FM.

Keywords: associative memory, fast mapping, feature overlap, lexical competition, semantic priming

Traditional theories of memory consolidation suggest that novel, arbitrary associations can initially be acquired quickly by means of hippocampal processing. In contrast to the initial fast acquisition, the incorporation of these associations into cortical long-term memory networks is a comparably slow and gradual consolidation process that is driven by hippocampal-neocortical interplay (see, e.g., Frankland & Bontempi, 2005, for a review). However, there is evidence that such time-consuming hippocampal-neocortical consolidation processes can be bypassed if the associations are encoded within a learning paradigm called *fast mapping* (FM; e.g., Himmer et al., 2017; Merhav et al., 2014, 2015; Sharon et al., 2011). In the typical FM paradigm, participants are presented with two pictures of objects, one of which is supposed to be *previously known* (e.g., a flamingo) whereas the other one is supposed to be *previously unknown* (e.g., an exotic, blue-footed bird; see Figure 1). Their task is to answer a question referring to a previously unknown label (e.g., "Does the satellote have blue feet"). To do so, participants need to recognize the previously known item, infer that the unknown label refers to the previously unknown item—thereby presumably incidentally creating a picture-label association—and respond to the question with regard to the unknown item.

Sharon et al. (2011) examined this learning paradigm in four amnesic patients experiencing severe lesions to the medial temporal lobe, predominantly to the hippocampus. These patients did not recognize the picture-label associations above chance level if the associations had been intentionally encoded within a standard explicit encoding (EE) task, in which they were explicitly asked to remember an unknown item together with its label. This might be attributed to their reduction in hippocampal volume because this is a task in which the hippocampus typically would be recruited. Strikingly, when the same patients encoded novel associations within the FM paradigm, their recognition performance was as good as that of healthy controls already immediately after encoding. This strongly indicates that FM provides a rapid and direct

Ann-Kathrin Zaiser https://orcid.org/0000-0002-3620-3518

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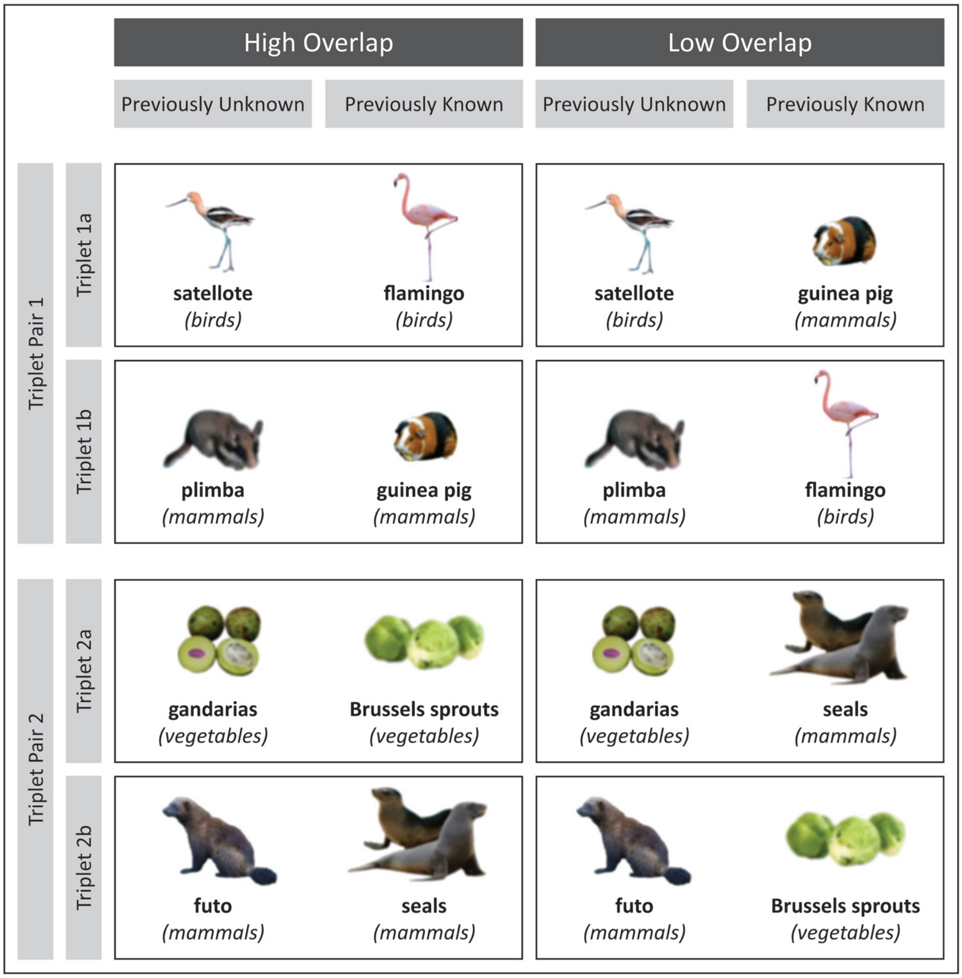
Correspondence concerning this article should be addressed to Ann-Kathrin Zaiser, Department of Applied Psychology, SRH University Heidelberg, Maria-Probst-Straße 3, D-69123 Heidelberg, Germany. Email: annkathrin.zaiser@gmail.com

Figure 1
Example Stimulus Material



Note. Each line depicts a picture triplet, consisting of one previously unknown item and two previously known items. Triplets were arranged in triplet pairs (e.g., Triplet Pair 1: Triplet 1a and 1b), within which overlap of the unknown and known items was counterbalanced. High-overlap item pairs were always from the same basic-level category (e.g., Triplet 1a: both birds). Low-overlap item pairs could consist of items from the same superordinate category but different basic-level categories (Triplets 1a and 1b: both animals, with birds and mammals as basic-level categories) or from different superordinate categories (Triplets 2a and 2b: plants and animals, with vegetables and mammals as basic-level categories), but note that we did not explicitly manipulate whether items were of the same versus different superordinate category in the FMLO condition. See the online article for the color version of this figure.

route to the integration of novel associations into cortical semantic memory networks, potentially bypassing slow hippocampal-neocortical consolidation processes.[1]

Despite this evidence that FM might enable successful direct integration of novel associations, other studies revealed contradictory findings (cf. Smith et al., 2014; Warren & Duff, 2014; Warren et al., 2016). Sharon et al. (2011) suggested three key determinants to be crucial for successful rapid semantic integration by means of FM: (a) Learning needs to be incidental; (b) The picture-label associations need to be actively discovered by the participants themselves through a process called *disjunctive syllogism*, that is, rejecting the previously known item to create a link between the label and the unknown item; (c) The new associations need to be learned in the context of previously known information, activating

[1] This does not necessarily mean that learning within the FM paradigm is always hippocampus-independent. It has been shown that the hippocampus contributes to learning through FM in healthy young adults (Atir-Sharon et al., 2015; Zaiser et al., 2020) or at least it cannot finally be excluded that it is involved (Merhav et al., 2015). We propose that in patients with severe and selective hippocampal lesions, it is valid to conclude that hippocampal processing cannot have contributed to FM encoding or retrieval. In young and healthy adults, in contrast, the appropriate question to ask is if rapid cortical integration is possible—irrespective of potential (additional) hippocampal involvement.

already existing semantic structures into which the new information can be integrated. Based on Merhav et al. (2014), Atir-Sharon et al. (2015) later added that the novel associations must not interfere with previously learned information. However, there are studies in which these criteria were entirely fulfilled but still, no rapid integration of novel associations into semantic memory networks was observed (e.g., Smith et al., 2014). Hence, these criteria might be essential but not necessarily sufficient for successful rapid and direct cortical integration of associations by means of FM, and yet undiscovered parameters possibly moderating rapid semantic integration through the FM paradigm still need to be identified.

Importantly, we do not consider FM to be a distinct learning mechanism (see Cooper et al., 2018, for a similar notion) but rather define it as a paradigm that comprises multiple cognitive operations, which together enable rapid cortical integration, potentially in a similar way as in other paradigms (e.g., unitization paradigms; see, e.g., Haskins et al., 2008; Parks & Yonelinas, 2015). A promising approach to identify factors driving rapid cortical integration within the FM paradigm could thus be to ask which cognitive operations are involved, which underlying neurocognitive processes might drive rapid cortical integration within the FM paradigm, and by which brain structures this could be supported. We suggest that the key cognitive operations involved in FM comprise the *discrimination* between complex objects, the *binding* of the picture of the unknown item to the label, and finally, the *integration* of this newly built picture-label association into cortical memory networks. With regard to neurofunctional correlates of learning through FM, most of the previous literature points to the anterior temporal lobe (ATL) as a structure critical for FM (e.g., Atir-Sharon et al., 2015; Greve et al., 2014; Merhav et al., 2015; Sharon et al., 2011). This fits nicely with the notion that the ATL serves as an amodal semantic hub, semantically integrating information from modality-specific cortices (see Lambon Ralph et al., 2017, and Patterson et al., 2007, for reviews). It is therefore plausible that anterior temporal structures may serve as a system supporting rapid semantic *integration* through FM. Prior to semantic integration of the picture-label association, however, participants need to *discriminate* between the unknown and the known item and *bind* the picture of the unknown item to the label as a prerequisite for semantic integration of the complete association. The discrimination between complex and especially highly similar objects is ascribed to the perirhinal cortex (PrC; e.g., Barense et al., 2007; Bussey et al., 2002, 2005; Cowell et al., 2010; Mundy et al., 2012), a structure located in the anterior part of the medial temporal lobe. One reason that makes the PrC qualified for the discrimination between highly similar objects is that it is also involved in the binding of elemental item features to coherent units that are processed in their exact configuration (e.g., Barense et al., 2005; Bussey et al., 2002, 2005; Cowell et al., 2010). However, PrC-mediated binding is not restricted to the binding of features to distinct, coherent items. Perirhinal binding processes have also been proposed for the binding of arbitrary associations between distinct items, given that these item-item associations are processed as a single unit (Haskins et al., 2008; Quamme et al., 2007). Interestingly, the amnesic patients with selective hippocampal lesions who showed a clear benefit from FM in the study by Sharon et al., (2011) encoded the unknown pictures together with highly similar known items (see also Sharon, 2010). This would typically recruit the PrC as it requires the discrimination between highly similar objects. Within the same study, two other patients with lesions to perirhinal and anterior temporal structures did not show such a benefit from FM encoding. It is therefore conceivable that the computational mechanisms of the PrC during the processing of pictures of complex and especially highly similar items and the binding of an unknown item and a label to a unit might be especially qualified to support the encoding and rapid integration of picture-label associations into semantic memory.

If the PrC indeed plays a key role in rapid integration of associations through FM, increasing the demands on perirhinal functions during FM encoding, as, for example, evoked by a high similarity between the unknown and the known item, might foster the rapid integration into neocortical networks.[2] It has already been suggested that a key characteristic of the FM paradigm is that the unknown item must be encoded in the context of a previously known item that provides an appropriate context for the new item to be integrated into semantic memory networks (e.g., Coutanche & Thompson-Schill, 2015; Mak, 2019; Sharon et al., 2011; see also Coutanche & Thompson-Schill, 2014, Experiment 2, for evidence of the necessity of the presence of a known item for lexical item-level integration of the labels). However, neither semantic nor perceptual similarity between the unknown and the known item, which might both trigger perirhinal involvement at object discrimination (see, e.g., Martin et al., 2018), has yet been manipulated systematically. We predict that a high feature overlap between the unknown and the known item in the FM task promotes rapid neocortical integration as a result of increased demands on (PrC-driven) object discrimination, which we tested in Experiments 1 and 2.

The conditions that are typically compared in most FM studies, that is, FM and EE, not only differ in the number of items in the encoding screen (and thus, the necessity of object discrimination) but also in other aspects, such as the intention to remember the associations. Like object discrimination, effects of *a learning intention* on rapid semantic integration through FM has, to our knowledge, not yet been manipulated systematically, although it has been speculated whether an episodic route to cortical integration and a direct cortical pathway might possibly run in parallel or suppress each other (e.g., Cooper et al., 2018; see also Hebscher et al., 2019). Previous literature has revealed that in amnesic patients with severe lesions to the hippocampus, the postmorbid acquisition of novel semantic knowledge seems to benefit from the absence of a learning intention (see, e.g., Duff et al., 2006; Westmacott & Moscovitch, 2001). It is conceivable that the explicit instruction to remember an association leads to a shift of cognitive resources toward a hippocampal-neocortical route to memory consolidation. In patients in whom this route is not available because of lesions to the hippocampus, triggering this hippocampal-neocortical route to semantic integration might lead to the inability to acquire new semantic knowledge. When there is no intention to explicitly learn an association, other

[2] It is important to note that although higher demands in general can be very resource-consuming and could therefore lead to worse memory, we refer to higher demands selectively on processes presumably involved in FM, that is, amongst others, the discrimination between highly complex objects.

mechanisms that might enable rapid and direct cortical integration might come into effect (see Sharon, 2010). In Experiment 3, we set out to investigate the effects of a learning intention on rapid semantic integration through FM in healthy young adults, who can rely on a hippocampal route to cortical integration of new semantic knowledge. Based on the assumption that a learning intention prevents learning in individuals with lesions to the hippocampus and based on our hypothesis that the discrimination between highly similar objects might be beneficial due to a greater PrC involvement, we expected that rapid semantic integration by means of FM is possible if highly similar objects need to be discriminated and if learning is incidental. However, it is unclear whether a learning intention inhibits a rapid and direct route to cortical integration or if cortical integration can be achieved via a slow hippocampal and fast perirhinal route in parallel.

To test the effects of *object discrimination* and *learning intention* on rapid cortical integration in the experiments reported here, we made use of implicit measures of cortical integration. One problem of using explicit recognition tests to assess cortical integration in young and healthy adults is that neocortical and hippocampus-based retrieval cannot be disentangled by comparing performance in such tests at a given time point (see, e.g., Coutanche, 2019; Gilboa, 2019; Zaiser et al., 2019). Instead of recognition performance, there are better indicators for a rapid and direct pathway to cortical integration. One could be differential memory dynamics for associations acquired through FM versus EE. This was shown in a study by Himmer et al. (2017), where no consolidation effects overnight were observed if associations have been immediately integrated through FM (see Merhav et al., 2015, for analogous fMRI results). Similarly, indicators for a rapid and direct route to cortical integration may be found using implicit measures of direct cortical integration. For example, larger proactive and retroactive interference effects (by assigning two labels to one unknown item) were found for FM than for EE. This could be attributable to the absence of protective effects of hippocampal pattern separation in the FM condition (see Merhav et al., 2014; see also Gilboa, 2019). Apart from interference effects, other implicit measures that provide direct access to lexical or semantic networks represented in cortical structures can also serve as indicators of cortical integration in healthy young adults.

To assess lexical and semantic integration through FM, we compared the effects of different encoding conditions on the processing of already known lexically (Experiment 1) and semantically (Experiments 2–4) related items, following a procedure used by Coutanche and Thompson-Schill (2014). They argued that successful integration of new associations into neocortical structures should result in lexical competition on one hand, and in semantic priming on the other hand. In Experiment 1, we examined effects of object discrimination on lexical integration by means of FM separately for a condition in which the previously unknown and the known item share many features (*fast mapping*, *high overlap*; FMHO) compared with a condition in which they share few features (*fast mapping*, *low overlap*; FMLO). We assumed that rapid integration into lexical networks can be fostered by a high feature overlap between the previously unknown and the known item at encoding. In Experiment 2, we investigated whether rapid semantic integration is also more pronounced in an FMHO condition than in an FMLO condition. To examine whether a potential semantic priming effect is specific for the FMHO condition, we further assessed semantic priming in an EE condition, for which we did not expect to observe a similar effect. To examine stability over time, we assessed semantic integration both immediately after encoding and again after 24 hr.

Although consistent with the expected effect of higher demands on object discrimination, a potentially larger semantic priming effect for the FMHO condition compared with the FMLO condition could also be attributed to distracting effects of the presence of a low-overlap known item in the FMLO condition (instead of a beneficial effect of the FMHO condition). In particular, a less similar known item might not only be unsupportive but might even prevent from processing the unknown item in its exact configuration because in the FMLO condition, it might take more time and effort to process two pictures with very dissimilar features. To examine whether it is the high feature overlap that is actually beneficial for rapid semantic integration through FM, we compared the FMHO condition to an incidental encoding (IE) condition, in which only the unknown item was presented, in Experiments 3 and 4. In Experiment 3, we examined not only effects of object discrimination but also effects of learning intention on rapid semantic integration in an orthogonalized manner. We contrasted semantic priming effects in the FMHO and IE condition, in both of which encoding was incidental, with two conditions in an intentional learning group, who encoded the associations within an intentional FMHO (intFMHO) condition and a typical EE condition.

Experiment 1

If new verbal information, such as a newly learned label of a previously unknown item, lexically competes with other entries of (cortically represented) lexical networks, it can be concluded that this newly learned information has been successfully integrated into these lexical networks. Generally, lexical competition leads to inhibition owing to interference caused by coactivation of lexically neighboring items at retrieval. Consequently, it takes more time until a target word is uniquely identified if it has more lexical neighbors (e.g., slowed response times to *mouse* as it has many lexical neighbors such as *house*, *horse*, etc.). Coutanche and Thompson-Schill (2014) found lexical competition, that is, slowed responses to English words which lexically neighbored the labels of an FM encoding phase, 10 minutes after encoding and again after 24 hr. For the EE group, no lexical competition was observed, neither immediately nor on the following day, indicating that rapid and persistent lexical integration is possible after encoding through FM but not EE.

Analogously to Coutanche and Thompson-Schill (2014), we used a lexical competition task to assess rapid lexical integration of the labels. For this purpose, labels in the encoding task needed to be artificially created lexical neighbors of already existing German words. Lexical competition should especially be found if these real words are so-called hermit words, that is, words which are not transformable into other words by changing one letter. If such hermit words that naturally do not have any lexical neighbors (e.g., *tomato*) obtain a new lexical neighbor at encoding (e.g., if the label *torato* is successfully learned), the relative increase of the number of neighbors of the hermits is large. Therefore, competition effects are expected for responses to hermits that obtained a new neighbor at encoding but only if this new neighbor has been successfully integrated. We expected to observe a general lexical competition effect for associations acquired by means of FM. This competition effect was assumed to be larger when the known and the unknown item share many features (FMHO) than when they share few features (FMLO). Because stable lexical competition effects for FM and no effects for EE have previously been reported (Coutanche & Thompson-Schill, 2014), we decided to only set focus on the effects of feature overlap within the FM paradigm in Experiment 1. In addition to this implicit measure of integration, we conducted a forced-choice recognition test in this and all other experiments reported here to test whether recognition memory performance was above chance. Moreover, assessing recognition accuracy was necessary to tell whether a potential lack of cortical integration effects would have been an issue of encoding difficulties (e.g., too short presentation times, too difficult questions, etc.) or if selectively rapid neocortical integration was not successful but there still was explicit (perhaps hippocampal) learning. We did not make assumptions about differences in recognition accuracy between the overlap conditions because it cannot be disentangled whether recognition accuracy in healthy young participants is driven by hippocampus-dependent retrieval or by retrieval of associations already incorporated into lexico-semantic networks.

Method

Participants

Thirty-six students from Saarland University took part in the experiment (31 female; M_{age} = 23.4 years, age range: 20–30 years). They completed the experiment within approximately 50–60 minutes. As in all other experiments reported here, all participants were native German speakers, had normal or corrected-to-normal vision, gave written informed consent prior to the experiment, and were compensated for their participation with 8€ per hour. Also, as all other experiments within this article, the experiment was approved by the local ethics committee of Saarland University in accordance with the declaration of Helsinki.

Materials

All pictures were obtained from the Internet and were drawn from an item pool of a previously conducted rating study, in which a different sample of 46 participants (30 female; M_{age} = 23.1 years, age range: 18–34 years) had rated pictures of items of eight categories (mammals, birds, insects, fish, reptiles, fruit, vegetables, plants) for familiarity (5-point Likert scale; 1 = *not at all familiar*, 5 = *very familiar*), previous knowledge (“known” vs. “unknown”), and feature overlap between the pictures of the unknown and known item of an item pair (1 = *not at all similar*, 5 = *very similar*). In the instructions of the rating study, feature overlap was defined as the number of features two pictures have in common. Examples made clear that features could be the presence and nature of fur, a tail, a fin, legs, the smoothness of a fruit’s skin, color, and so forth. To manipulate feature overlap between the putatively known and the putatively unknown items in the subsequent experiments, each of 92 putatively unknown items was paired with two putatively known items (one with high, the other one with low overlap; see Triplet 1a in Figure 1 for an example). In a corresponding triplet (e.g., Triplet 1b in Figure 1), these two putatively known items were paired with another unknown item in the respective other overlap condition. Such two interrelated triplets, comprising two unknown and two known items in sum, will be referred to as triplet pair. This arrangement made it possible that each unknown item and each known item could be encoded in each overlap condition, which allowed for counterbalancing.

When deciding which item pairs of the rating study should be included in the experiments reported here, we first made sure to exclude all putatively known items that had been judged as unknown by most participants of the rating study and all putatively unknown items that had been judged as known by most participants. We then further selected the associations based on the familiarity ratings, which allowed for a more fine-grained choice. In Experiment 1, the previously unknown items had been classified as unknown by 87% (SD = 12%) of the participants in the rating study and had obtained familiarity ratings of M = 2.09 (SD = 0.45). The previously known items had been rated as known by 91% (SD = 12%) of the participants in the rating study and had obtained familiarity ratings of M = 4.41 (SD = 0.39). Also, triplets were only included if the respective other triplet of a triplet pair also had obtained good ratings, in order to allow for full counterbalancing. In the final item set of this and all other experiments reported here, familiarity for the previously unknown items was significantly lower than for the previously known items and significantly more participants of the rating study had rated the previously known item as known than the previously unknown items (both $ps < .001$). Only the triplet pairs with the highest difference between the overlap ratings of the high-overlap item pairs (e.g., satellote–flamingo; see Figure 1) and the low-overlap item pairs (e.g., satellote–guinea pig) were included (M_{FMHO} = 3.57, SD_{FMHO} = 0.49; M_{FMLO} = 1.41, SD_{FMLO} = 0.32; M_{diff} = 2.16, SD_{diff} = 0.56). In the final item set of this and all following experiments reported here, overlap of the high feature overlap pairs was significantly higher than overlap of the low feature overlap pairs ($p < .001$). In addition, the high overlap item pair with the lowest overlap still had a higher overlap rating than the low overlap item pair with the highest overlap. The size of all pictures in all four experiments reported here varied depending on their relative size in reality, but was 300 × 300 pixels at maximum, leading to a maximum visual angle of approximately 8.2°.

For counterbalancing, triplets were arranged in two lists, which were assigned to one half of the sample each. In each list, 46 item pairs (taken from 23 triplet pairs) were presented in the FMHO encoding condition and 46 pairs (taken from different 23 triplet pairs) in the FMLO condition (counterbalanced between lists). Lists did not differ between participants with regard to feature overlap ratings, neither for FMHO trials nor for FMLO trials (both $ts < 1$). Between overlap conditions, semantic categories of the items were distributed equally, and items did not differ with regard to familiarity ratings or ratings of previous knowledge, neither of the previously known nor the unknown items (all $ps > .219$). Within each overlap condition, 50% of the questions at encoding required a positive response, 50% a negative response, and the question referring to a previously unknown item was identical for both overlap conditions.

To measure lexical competition, we created 48 new lexical neighbors to existing concrete German nouns (see Appendix A). We will refer to the latter as hermits, albeit eleven of them already had one lexical neighbor[3] (but with a mean normalized lemma frequency of the neighbors of < 0.01 per million words, $SD < 0.01$; treating German umlauts as distinct letters, i.e., *ö* was considered as different from *o*; Dudenredaktion, 2009; Heister et al., 2011). Word length of the hermits was between four and eight letters (M = 6.50, SD = 0.98), and normalized lemma frequency was between 0.52 and 133.94 per million words (M = 19.58, SD = 34.25; Heister et al., 2011). The artificially created new labels should deviate from the hermit words in one phoneme at maximum, either by adding, deleting, or substituting a phoneme, and this deviation should preferably occur late in the word, in order to shift the point of uniqueness backward and thus provoke maximum lexical competition with the hermits (Davis & Gaskell, 2009; Gaskell & Dumay, 2003). Of the 48 newly created labels, 32 were used as labels in the encoding phase (16 within FMHO trials, 16 within FMLO trials) and their respective hermits were later used as *neighbor hermits* in the lexical competition task (e.g., *satellite* tested as neighbor hermit if the label *satellote* was encoded; see Appendix B for a schematic overview). The remaining 16 labels were not encoded since their direct lexical neighbors were used as *nonneighbor hermits* in the lexical competition task (e.g., *satellite* as nonneighbor hermit if the label *satellote* was not encoded). The allocation of labels to neighbor hermit FMHO trials, neighbor hermit FMLO trials, or nonneighbor hermit trials was counterbalanced between subjects, which required that each item was assigned to three labels, with each appearing together with this item in one third of the participants (see Appendix B). Not all 92 trials of the encoding phase were used for the lexical competition task in order to prevent that participants realize that all labels were neighbors to real words, which could have led to the development of strategies. It was additionally ensured by a posttest examination that they did not notice the lexical neighborhood. Labels of the remaining 60 items that were not used for the lexical competition task were substituted either with a pseudoword or with an item's botanical or zoological name (sometimes slightly modified) if these labels might have subjectively triggered expectations about an item's category or features. For example, items were renamed if parts of the name included information about the category, such that *giraffe gazelle* (which was given its alternative name *gerenuk* in our experiments) would indicate that the item is an animal. Word length of all labels, including the newly created neighbors of the hermits, was between four and 10 letters (M = 7.21, SD = 1.17).

Each test display in the two-alternative forced-choice recognition test consisted of a label used in the encoding phase, its respective associated picture, and one foil picture. Test foils had all been used as previously unknown items in the encoding phase to control for item familiarity. Moreover, both pictures of a test screen were from the same superordinate category: They were either both plants or both animals. Thus, it was not sufficient to remember an item's semantic category. All text stimuli throughout the experiments of this article were printed in Arial 27-point font.

Design and Procedure

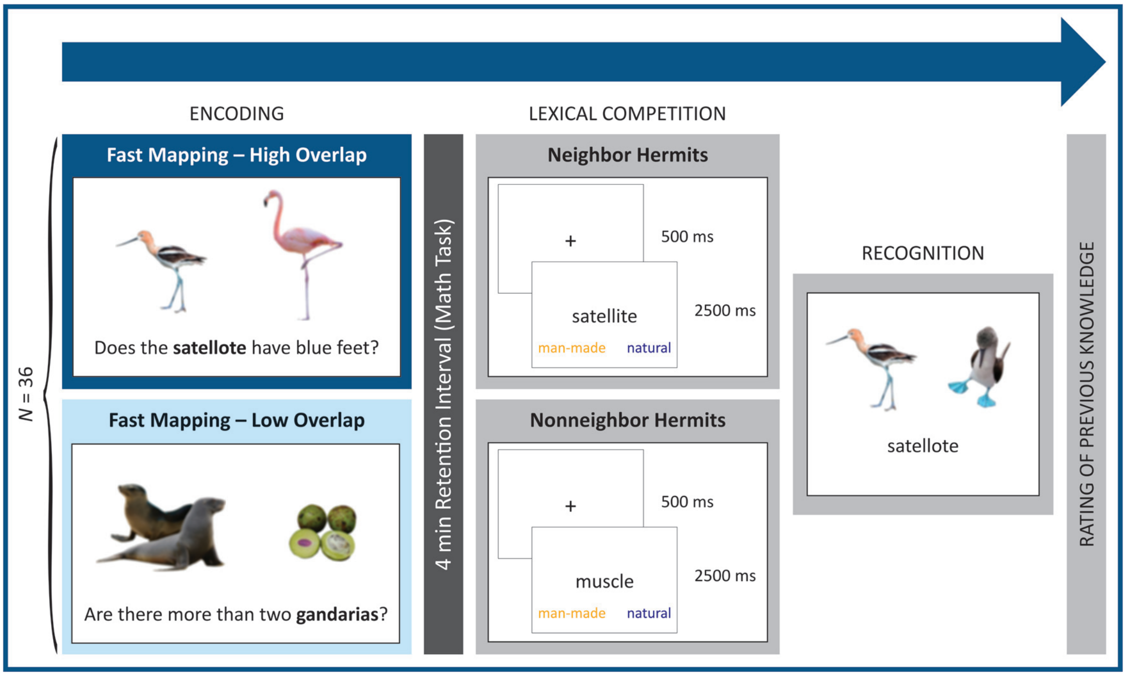
In this and all following experiments, stimulus presentation and timing were controlled using the experimental software PsychoPy (Peirce, 2008; http://www.psychopy.org/). Participants were seated in front of a 17-in. screen, at a viewing distance of approximately 60 cm. All stimuli throughout the experiment were presented against a white background.

Encoding. To ensure that encoding was incidental, participants were told that the experiment aimed to investigate visual perception of animals, fruit, vegetables, and plants (which also applies for all other incidental-learning groups reported within this article). All participants encoded the associations by means of FM, and feature overlap was manipulated within subjects. Participants first completed six practice trials (three FMHO, three FMLO), followed by the 92 experimental trials. To prevent participants from always responding with regard to the unknown item without paying attention to the label, additional 24 item pairs (12 FMHO, 12 FMLO) were inserted as filler trials, in which the question referred to the previously known item (e.g., "Is the cat's tail pointed up?"). Filler trials were excluded from all analyses (as in all experiments of this article). All trials were presented in random order with the constraint that stimulus presentation began and ended with two filler trials each, which were used as buffer trials to prevent primacy and recency effects. At the beginning of each trial, a fixation cross was displayed for 700 ms, horizontally centered and slightly below the center of the screen, at the same height as the question would appear. The question was then displayed for 5,500 ms, with the plain text presented separately for the first 2,000 ms and together with the pictures for 3,500 ms (see Figure 2). The label within the question was always presented in the horizontal center of the screen and in bold font. Participants were encouraged to read the question thoroughly, focus on what exactly is asked for, and, as soon as the pictures appear, to figure out to which item the question refers and how it is thus to be answered. After the pictures and the question had disappeared, the words *yes* and *no* were displayed in orange and blue color on the left and right side of the screen (color and position counterbalanced between subjects), requesting to press the key marked with the respective color on a computer keyboard. As soon as an answer had been given, participants received feedback and the next trial started. If no answer had been given within 3,000 ms, they were encouraged to respond faster and moved on to the next trial.

Lexical Competition. In this and all other experiments reported here, the encoding phase was followed by a four-minute retention interval, in which participants solved simple mathematical equations, before the respective test phases started. In this experiment, a lexical competition phase was administered after the retention interval. First, participants were familiarized with the task in a practice phase consisting of four trials using German nouns that did not appear elsewhere in the experiment. In contrast to the experimental trials, feedback was given at the end of each

[3] Note that to observe lexical competition, it is not necessary to use actual hermits as targets. Using hermit words only maximizes the likelihood to observe lexical competition as the incremental competition through a new neighbor is the largest. Using words that already have a lexical neighbor is therefore not a limitation with regard to the interpretation of potential effects.

Figure 2
Experimental Design and Procedure of Experiment 1



Note. Encoding: After the question had been presented for 2,000 ms, pictures were inserted and presented together with the question for 3,500 ms. Response options (yes/no) were provided after both pictures and question had disappeared. Of 92 unknown items, 32 were renamed to serve as new lexical neighbors for the lexical competition task (e.g., *satellote* as a neighbor for the hermit *satellite*). Feedback was given after a response had been made. Note that in the actual experiment, the labels were always presented in the horizontal center of the screen. Lexical competition: In the lexical competition task, responses were given to 32 hermits that had obtained a new neighbor at encoding (neighbor hermits) versus 16 hermits that had not obtained a new neighbor (nonneighbor hermits). Sixteen lexical neighbors of the 32 hermits were encoded in the FMHO (fast mapping, high overlap) condition and 16 in the FMLO (fast mapping, low overlap) condition. Recognition: In the two-alternative forced-choice recognition test, targets and foils within one display always belonged to the same superordinate category (i.e., either both items were animals or both items were plants). See the online article for the color version of this figure.

practice trial and participants were encouraged to respond faster if they had not responded within the given time window of 2,500 ms. The actual lexical competition task contained 48 trials, which were presented in random order. Each trial began with a fixation cross in the center of the screen for 500 ms, followed by the presentation of the hermit word (see Figure 2). Participants were instructed to decide if a hermit is man-made or natural by keypress. The words *man-made* and *natural* were displayed in blue and orange color on the left and right side on the bottom of the screen (color and position counterbalanced between subjects). The next trial started as soon as a response was given but after 2,500 ms of stimulus presentation at maximum. Instructions emphasized speed over accuracy and participants were additionally informed that because of the fast pace of the task, they might make mistakes but nevertheless should focus on responding as fast as possible.

Recognition. In the recognition test, participants were presented with two pictures and a label and were asked to indicate which of the pictures belonged to the label. After the presentation of a fixation cross for 500 ms in the center of the screen, the label was displayed horizontally centered slightly underneath the position of the fixation cross, together with a test target and a test foil picture to the left and to the right (50% of the target and foil pictures on each side) slightly above the position of the fixation cross (see Figure 2). This test display stayed on the screen until a response was made by pressing the respective left or right key on the computer keyboard, but for 3,500 ms at maximum. If no key had been pressed within this time, participants were encouraged to respond faster and the next trial started. All 92 picture-label associations were tested, including the 32 associations of which the neighbor hermits were presented in the lexical competition task. Each picture of an unknown item was presented twice, once as target and once as foil. To prevent participants from developing strategies, additional 12 filler trials (consisting of 24 pictures of unknown items) were included, in which both pictures had already been presented twice. Repeated presentations of a picture were separated by at least eight trials and no combination of test pictures appeared twice. Both pictures of a test display had been encoded within the same encoding condition. Again, this phase was also preceded by a practice phase, in which the items from the encoding practice phase were used as test items. Feedback was given only in the practice phase.

Rating of Previous Knowledge. At last, previous knowledge of all items was assessed with a rating scale. After debriefing participants about the intention of the study and the renaming of the stimuli, they were instructed to indicate on a 5-point Likert scale how well they had known each item before the experiment, no matter under which name (1 = *had not known the item at all before the experiment*; 5 = *had known the item very well before the experiment*). After ratings at or above 4, participants were asked to type in the item's name at the lowest category level possible (e.g., *hawk* instead of *bird*). We decided not to ask participants for both a dichotomous decision of previous knowledge and a familiarity rating in our experiments, as in the rating study, these scales were highly correlated ($r = .97$).

Data Analyses

All analyses reported in this article were conducted using R (R Core Team, 2016). Lexical competition effects were calculated by subtracting response times for correct responses to nonneighbor hermits from response times for correct responses to neighbor hermits. Trials were removed if they contained items for which a participant's individual rating of prior knowledge was inconsistent with the expected knowledge (rating of ≤ 3 for previously known items and ≥ 4 for previously unknown items; mean dropout rate: 5.7% of correct trials). We further excluded outlier trials with regard to response times individually for each participant according to the outlier criterion recommended by Tukey (1977; 1.5 interquartile ranges below the first and above the third quartile) and, in line with Coutanche and Thompson-Schill (2014; see also Bowers et al., 2005) and Coutanche and Koch (2017), all trials with response latencies below 300 ms and above 1,500 ms because too long response times are unlikely to be influenced by implicit processes. This resulted in a final mean dropout rate of 12.6% of correct trials. There were no outlier participants (Tukey, 1977) regarding the lexical competition effect. Recognition accuracy represents the proportion of correct responses. If not noted differently, t tests in this and the following experiments were one-tailed and the significance level was set to $\alpha = .05$. Effect size d for the within-subjects comparison of the lexical competition effect were calculated as difference between the mean lexical competition effects divided by the pooled standard deviation of the difference and corrected for the within-subjects correlation of the effects (see Morris & DeShon, 2002). Effect size d for the between-subjects deviation of the lexical competition effect from zero was calculated as the mean lexical competition effect divided by the standard deviation of the effect. Effect size d for the between-subjects deviation of recognition accuracy from zero was calculated as the mean recognition accuracy divided by the standard deviation of recognition accuracy. To be able to interpret putative null effects, which would not be legal using null hypothesis significance testing only (see, e.g., Dienes, 2014; Lakens et al., 2020; Rouder et al., 2009), we additionally report Bayesian statistics in this and all following experiments (calculated using the R BayesFactor package by Morey & Rouder, 2018; using the Jeffreys prior on variance and with a Cauchy prior on effect size scaled at $r = \sqrt{(2)}/2$, one- or two-tailed depending on the respective t test). For tests of equality, we report the Bayes Factor (BF) that indicates the strength of the support for the null model over the alternative hypothesis (BF_{01}).

Results

Lexical Competition

All participants performed above chance level in the lexical competition task ($p < .05$, binomial test; see Table 1 for accuracies). The accuracy difference between neighbor hermits and nonneighbor hermits was only marginally significant, $t(35) = -1.99$, $p = .054$, and neither reached significance for the FMHO condition, $t(35) = 1.78$, $p = .084$, nor for the FMLO *condition* $t(35) = 1.75$, $p = .090$, all two-tailed. Although we observed a lexical competition effect for the FMLO condition, $t(35) = 2.02$, $p = .025$, $d = 0.34$, but not for the FMHO condition, $t(35) = 1.10$, $p = .141$, $BF_{01} = 1.89$, there was a general lexical competition effect, $t(35) = 1.94$, $p = .030$, $d = 0.33$ (see Figure 3), that is, response times to neighbor hermits were significantly slower compared with nonneighbor hermits across both conditions (see Table 1). Lexical competition in the FMHO condition was numerically smaller than in the FMLO condition, contrary to our hypotheses. However, exploratory post hoc analyses revealed that the lexical competition effect was not significantly different between FMHO and FMLO trials, $t(35) = -.81$, $p = .423$, two-tailed, $BF_{01} = 4.12$.

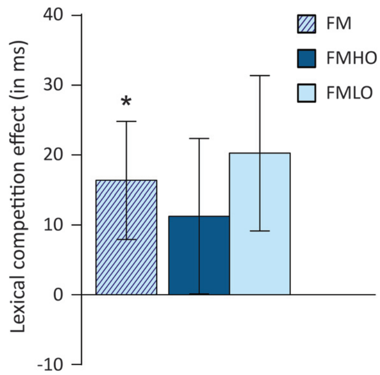
Although the pattern of the accuracy data (see Table 1) might indicate a tendency toward a speed–accuracy trade-off, differences

Table 1
Mean Response Times and Mean Accuracies for Neighbor Hermits and Nonneighbor Hermits by Encoding Condition in the Lexical Competition Task of Experiment 1

Measure	Encoding condition	Neighbor hermits	Nonneighbor hermits	Lexical competition effect(neighbor hermits – nonneighbor hermits)
Response times (in ms)	FM	865.35 (121.74)		16.36 (50.69)
	FMHO	860.22 (122.17)		11.24 (61.56)
	FMLO	869.24 (130.85)		20.25 (60.08)
			848.99 (113.69)	
Accuracies (in % correct)	FM	92.34 (5.09)		
	FMHO	92.96 (6.74)		
	FMLO	91.79 (7.82)		
			89.30 (9.92)	

Note. Lexical competition effects were calculated as response times for neighbor hermit trials minus response times for nonneighbor hermit trials. FM = fast mapping, irrespective of feature overlap; FMHO = fast mapping, high overlap; FMLO = fast mapping, low overlap; neighbor hermits = hermits that had obtained a new neighbor at encoding; nonneighbor hermits = hermits that had not obtained a new neighbor at encoding. Standard deviations in parentheses.

Figure 3
Results of the Lexical Competition Task of Experiment 1



Note. The lexical competition effect was calculated by subtracting response times for responses to words that had not obtained a new neighbor at encoding (nonneighbor hermits) from response times for responses to words that had obtained a new neighbor (neighbor hermits). FM = fast mapping, irrespective of feature overlap; FMHO = fast mapping, high overlap; FMLO = fast mapping, low overlap. Error bars for the FM condition represent the standard error of the mean for the lexical competition effect. Error bars for the FMHO and FMLO conditions represent the within-subjects standard error of the mean for the differences between the lexical competition effect in the FMHO condition and in the FMLO condition. * $p < .05$. See the online article for the color version of this figure.

in accuracies, which could reflect such a trade-off, did not reach significance. To further investigate whether a lexical competition effect is also apparent in a sample with an accuracy pattern contrary to what would indicate a speed–accuracy trade-off, we examined lexical competition in a subgroup of participants who showed numerically higher accuracies for nonneighbor hermits than for neighbor hermits. In this group (N = 16), a lexical competition effect was also found, $t(15) = -1.85$, $p = .042$, $d = 0.46$, one-tailed, indicating that even if a speed–accuracy trade-off could definitely be excluded, there still was rapid lexical integration.

Recognition

To investigate whether participants also showed above-chance explicit associative memory, we checked accuracy in the recognition test. Participants performed above chance level in the FMHO condition, $t(35) = 4.25$, $p < .001$, $d = 0.71$ ($M_{\text{FMHO}} = .56$, $SD_{\text{FMHO}} = .09$) and in the FMLO condition, $t(35) = 4.76$, $p < .001$, $d = 0.79$ ($M_{\text{FMLO}} = .58$, $SD_{\text{FMLO}} = .09$). Exploratory post hoc analyses revealed no difference between encoding conditions in recognition accuracy, $t(35) = .54$, $p = .590$, two-tailed, $BF_{01} = 4.87$.

Discussion

In Experiment 1, we observed a lexical competition effect already shortly after the labels had been encoded by means of FM. Thus, consistent with Coutanche and Thompson-Schill's (2014) results, our findings show that the labels of the novel associations were lexically integrated immediately after FM encoding.

In contrast to our expectations, the lexical competition effect for FMHO trials was not different from that for FMLO trials, and numerically even smaller. This suggests that lexical integration of the label on an item level does not seem to be affected by a manipulation of feature overlap and might therefore presumably be independent of perirhinal binding processes. It does not imply, however, that feature overlap does not affect semantic integration of the complete picture-label association (i.e., the integration of the label together with a semantic connotation provided by the picture) as pure lexical integration of the label on an item level is necessary but not sufficient for semantic integration on an associative level. Furthermore, it might not have been advantageous to manipulate feature overlap within subjects with trials of different overlap conditions presented in random order. Once participants expected that they have to discriminate between highly similar items, they might have maintained this task set throughout the encoding phase (see, e.g., Sakai, 2008). Consequently, they might have processed the items more in their exact configuration than if only low-overlap pairs had been presented, for which this would not have been required.

The semantic priming task we used as a measure of semantic integration in Experiment 2 should bring more clarity to the role of feature overlap in the integration of the label together with a semantic connotation instead of the pure lexical integration of the word form itself on an item level.

Experiment 2

To measure semantic integration of novel associations acquired by means of FM, Coutanche and Thompson-Schill (2014) conducted a semantic priming task. In contrast to lexical competition, which leads to *slowed* responses to neighbors of well-integrated lexical entries, a semantic priming effect indicates that access to semantically related items is facilitated (e.g., *faster* response times to *mouse* if it was preceded by *hamster*). The authors expected that in the FM condition, the newly learned labels of previously unknown animals would prime semantically related but not unrelated targets. Contrary to their expectations, no priming effects were found either for an FM or an EE condition after 10 minutes. After 24 hr, they found a significant priming effect for the FM group only. Unfortunately, because related targets in the priming phase were always animals and unrelated targets were always artifacts, semantic categories of the targets were not counterbalanced. Because response latencies between related and unrelated targets might have differed already on a baseline level, it cannot be excluded that faster processing of the artifacts could have masked a potential priming effect. This could have led to a general reduction of all semantic priming effects in their study or at least, it makes the interpretation more difficult. Therefore, Experiment 2 set out to test for semantic priming effects but with a few adaptations. Because we used items of different semantic categories at encoding, it was possible to prevent confounds by counterbalancing for categories of the priming targets. In addition, we used a task requiring a semantic instead of a lexical decision to provoke stimulus processing on a more elaborate semantic level. Most importantly, however, we manipulated feature overlap with the idea that rapid semantic integration as measured by means of semantic priming effects should especially be observed in an FMHO condition, compared with an FMLO condition or an EE condition. Like Coutanche and Thompson-Schill (2014), we administered a semantic priming task on two consecutive days. We predicted a priming effect shortly after encoding in the FMHO condition because high demands on object discrimination, which we assume to strongly trigger PrC involvement, should boost rapid semantic integration through FM. Consequently, this effect should be larger in the FMHO condition compared with the FMLO condition. For the EE condition, we predicted a priming effect only after 24 hr as there should have been enough time for gradual consolidation into neocortical structures. It cannot be excluded that there might also be hippocampal engagement at encoding in the FM conditions in young and healthy participants, which potentially could foster semantic priming after 24 hr of consolidation. However, hippocampal involvement in FM encoding is presumably much less than in the EE condition, in which learning is intentional. Because no direct integration should have taken place through FMLO encoding and hippocampal contribution to learning should be negligible, we did not expect a semantic priming effect in the FMLO condition on Day 2.

For the forced-choice recognition test, we expected better performance in the EE group than in the FM groups as healthy participants should benefit from the intention to learn in the EE condition. Again, we did not make predictions on differences in recognition accuracy between the two FM conditions (FMHO, FMLO).

Method

Participants

As encoding condition was manipulated between subjects, 120 participants were randomly allocated to one of three encoding conditions (FMHO, FMLO, EE). Four participants had to be excluded from all analyses because they had already taken part in another experiment in which the same stimulus material was used, leading to an overall sample size of $N = 116$ participants ($n_{\text{FMHO}} = 39$, $n_{\text{FMLO}} = 39$, $n_{\text{EE}} = 38$; 96 female: 32 in the FMHO condition, 33 in the FMLO condition, 31 in the EE condition; $M_{\text{age}} = 23.1$ years, age range: 18–35 years). There was no age difference between groups, $F < 1$. The experiment was split into two sessions of approximately 20–25 minutes each, separated by 24 hr (range: 23.4–24.4 hr).

Materials

Forty-eight triplets (of 24 triplet pairs) were drawn from the stimulus material of the previously conducted rating study (see Materials section of Experiment 1). The criteria of triplet selection were identical with those applied for Experiment 1. The previously unknown items used in Experiment 2 had been classified as unknown by 88% ($SD = 12\%$) of the participants in the rating study and had obtained familiarity ratings of $M = 2.01$ ($SD = 0.42$). The previously known items had been rated as known by 90% ($SD = 13\%$) and had obtained familiarity ratings of $M = 4.44$ ($SD = 0.41$). The mean difference between the overlap rating of a triplet's high-overlap item pair and its low-overlap item pair was $M_{\text{diff}} = 2.20$ ($SD_{\text{diff}} = 0.68$; $M_{\text{FMHO}} = 3.62$, $SD_{\text{FMHO}} = 0.53$; $M_{\text{FMLO}} = 1.42$, $SD_{\text{FMLO}} = 0.39$).

Labels remained the same as in Experiment 1. Those items which had been assigned three hermit neighbor labels for usage in the lexical competition task in Experiment 1 were given one of these three names. The labels used for Experiment 2 consisted of four to nine letters, with a mean length of $M = 6.13$ letters ($SD = 1.18$). In the two semantic priming phases, the labels of the previously unknown items were presented as primes, followed by a familiar German noun as target. Target words were either animals or plants. Each prime was assigned to four targets: two semantically related targets (same category as the prime) and two unrelated targets (different category). Unrelated prime-target pairs were created by reallocating targets to unrelated primes. All primes were presented twice, once on each day, whereas targets were only presented once. Within each participant, 25% of the primes were presented together with a related target only on Day 1, 25% only on Day 2, 25% on both days, and 25% on neither day. Assignment of trials to relatedness condition was counterbalanced across participants. Targets were of low frequency (lemma frequencies between 0.01 and 12.57 per million words; $M = 1.82$, $SD = 2.48$; Heister et al., 2011) and preferably long (4–13 letters; $M = 7.33$, $SD = 1.89$) because it has been shown that priming effects can be strengthened if processing of the target word takes participants more time (Hines et al., 1986). None of the targets had been presented previously in the experiment, neither as words nor as pictures of previously known items in the encoding phase. All prime and target words were displayed in the center of the screen.

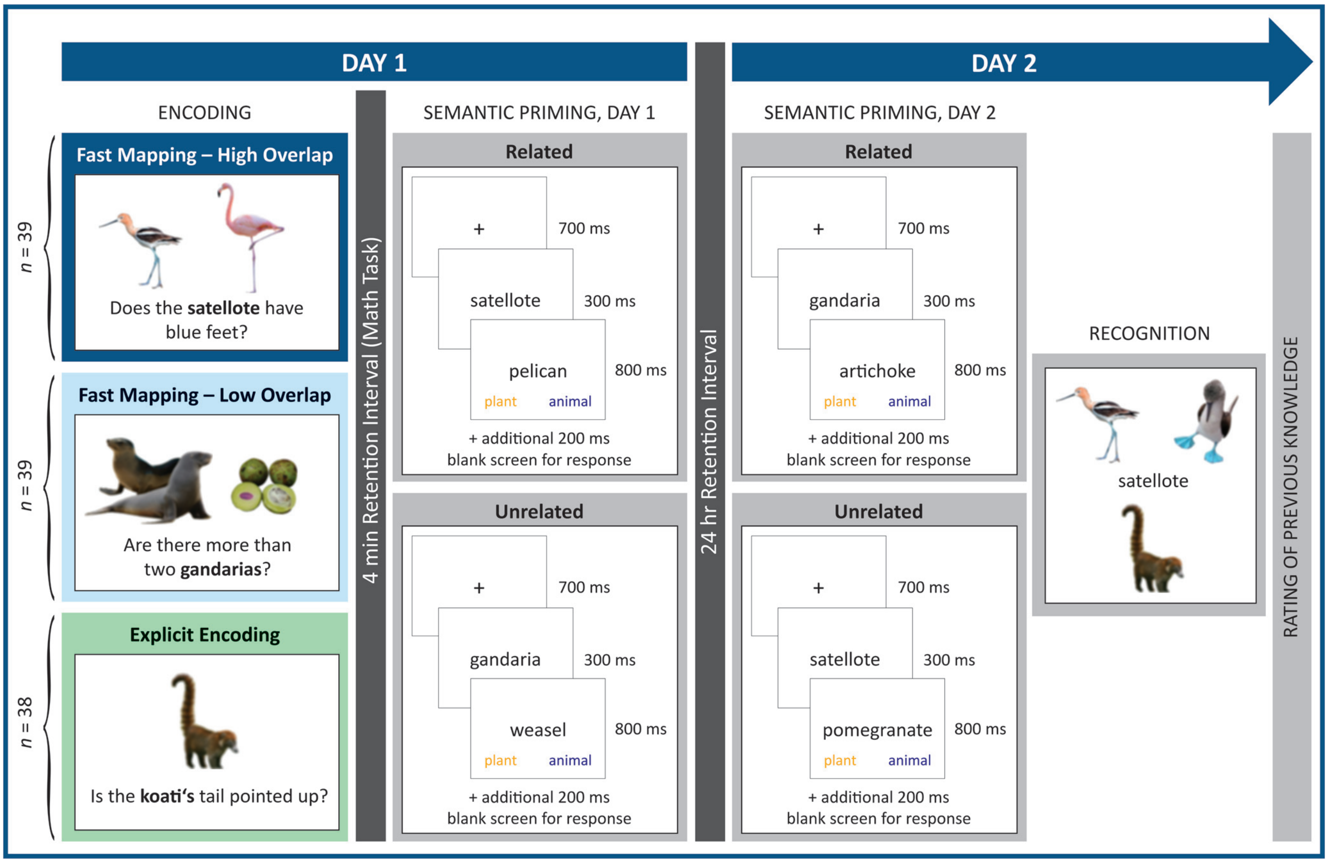
For the three-alternative forced-choice recognition test, the target picture was paired with two foil pictures from the same superordinate category (either all plants or all animals). All pictures appeared three times (once as target, twice as foil), separated by at least four trials. All other constraints were as in Experiment 1.

Design and Procedure

Encoding. The experimental settings for all three groups (FMHO, FMLO, EE), the cover story, and the encoding procedure for the two FM groups were equal to Experiment 1. In contrast to the FM groups, learning was intentional in the EE group. They were informed about the memory test right at the beginning of the experiment, and, in particular, that they would later be tested on the exact combination of the picture together with its label. Right before the encoding phase, they were again explicitly instructed to remember the items together with their names. In the EE encoding phase, participants were only presented with the picture of the previously unknown item (see Figure 4). Contrary to previous studies (cf. Atir-Sharon et al., 2015; Coutanche & Thompson-Schill, 2014; Greve et al., 2014; Himmer et al., 2017; Korenic et al., 2016; Merhav et al., 2014, 2015; Sharon et al., 2011; Smith et al., 2014; Warren & Duff, 2014; Warren et al., 2016), the EE group was presented with the same questions as the FM groups, to prevent any confounds attributable to inconsistencies in task demands apart from the critical FM determinants. Sixteen additional filler trials (including four buffer trials; matching each participant's encoding condition) were randomly inserted. Before the actual experiment started, all three groups conducted a practice phase of six encoding trials. Stimulus presentation was as in Experiment 1.

Semantic Priming. All following phases were identical for the three groups. Both priming phases were preceded by a practice phase of six trials, in which primes were pseudowords that had not appeared in the encoding phase. To accustom participants to the task demands, two buffer trials of the same nature as the practice trials were inserted at the beginning of each priming phase. Each trial began with the presentation of a fixation cross in the center of the screen for 700 ms, followed by a prime for 300 ms, which was the label of a previously unknown item of the encoding phase (see Figure 4). Next, the prime was replaced by the target, which

Figure 4
Experimental Design and Procedure of Experiment 2



Note. Encoding: In contrast to the fast mapping conditions, participants in the explicit encoding condition were explicitly instructed to remember the item. After the question had been presented for 2,000 ms, pictures were inserted and presented together with the question for 3,500 ms. Response options (yes/no) were provided after both pictures and the question had disappeared. Feedback was given after a response had been made. Note that in the actual experiment, the labels were always presented in the horizontal center of the screen. Semantic priming: For the semantic priming phases on Day 1 and Day 2, relatedness was fully counterbalanced across participants and study–test delays. Recognition: In the three-alternative forced-choice recognition test, the screen was presented as depicted in the figure for 3,000 ms and then a prompt to respond appeared at the bottom of the screen. Targets and foils within one display always belonged to the same superordinate category (i.e., either both items were animals or both items were plants). See the online article for the color version of this figure.

was either semantically related or unrelated to the prime. The participants' task was to indicate by keypress if the target was an animal or a plant, and, as in Experiment 1, instructions emphasized speed over accuracy. Participants were informed that due to the fast pace of the task, they might make mistakes but nevertheless should focus on responding as fast as possible (as recommended by Wentura & Degner, 2010). The words *animal* and *plant* were displayed in blue and orange color on the left and right side on the bottom of the screen (color and position counterbalanced between subjects). Targets remained on the screen until participants responded by pressing the respective orange or blue key on the computer keyboard but for 800 ms at maximum. If no key had been pressed within 800 ms of target presentation, a blank screen was inserted for additional 200 ms in which the target was not visible but responses were still recorded. All stimuli of the priming phase of this and the following experiments were presented in random order in the center of the screen. After a delay of 24 hr, a second priming phase was administered, in which the same primes were presented as on Day 1 but together with different targets. Apart from that, the procedure was kept identical with the Day 1 priming phase.

Recognition. The three-alternative forced-choice recognition test was only administered after the completion of the second priming phase on Day 2, in order to prevent a recognition task on Day 1 from influencing the Day 2 semantic priming results. A fixation cross was displayed in the center of the screen for 500 ms, before it was replaced by the recognition test label (see Figure 4). The test target picture and the two test foil pictures were arranged around the label, with their positions on the screen randomly assigned (top-left, top-right, bottom-center). Participants were instructed to indicate which of the three pictures belonged to the test label by clicking on the respective picture. To ensure that all participants had enough time to thoroughly look at all three pictures, responses could not be given before 3,000 ms of stimulus presentation, after which a verbal prompt to respond appeared at the bottom of the screen. As soon as a decision had been made, the next trial started and the mouse cursor was automatically set back to the center of the screen. If no key had been pressed within 6,000 ms of stimulus presentation, participants were encouraged to respond faster and the next trial started.

Rating of Previous Knowledge. Rating instructions and procedure were identical to Experiment 1, except that a 6-point Likert scale was used (1 = *had not known the item at all before the experiment*; 6 = *had known the item very well before the experiment*). If a rating of ≥ 4 was given, participants were asked to type in the item's name at the lowest category level possible.

Data Analyses

The semantic priming effect was calculated by subtracting response times for correct responses to related targets from response times for correct responses to unrelated targets, individually for each participant. Analyses included all correct trials for which the individual ratings of both the known and the unknown item (EE: only the unknown item) were congruent with the expected knowledge, that is, items classified as unknown in the rating study with an individual knowledge rating of ≤ 3, and items previously classified as known with a rating of ≥ 4 (mean dropout rate was 7.7% for both days). Further trials were excluded if response latencies were 1.5 interquartile ranges below the first quartile or above the third quartile of individual response times (Tukey, 1977).

For Day 1 analyses, nine participants had to be excluded because they had not performed above chance level in the semantic priming task (two participants of the FMHO group, three FMLO, one EE; $p > .05$, binomial test) or were outliers with regard to the semantic priming effect according to Tukey (1977; one FMLO, two EE), resulting in an overall sample size of $N_{\text{Day1}} = 107$ ($n_{\text{FMHO}} = 37$, $n_{\text{FMLO}} = 35$, $n_{\text{EE}} = 35$). Participants who were classified as outliers with regard to the priming effect were again included in Day 2 analyses, whereas chance performers were excluded from all further analyses as we took low performance in such an easy task as an indicator of a lack of motivation and subsequent performance would likely be based on less overall attendance to the stimuli.

In addition to the chance performers of Day 1, two more participants were excluded for the same reason on Day 2 (1 FMLO, 1 EE). Four participants were outliers regarding the priming effect on Day 2 (4 FMHO), resulting in an overall sample size of $N_{\text{Day2}} = 105$ ($n_{\text{FMHO}} = 34$, $n_{\text{FMLO}} = 35$, $n_{\text{EE}} = 36$). For the recognition test, only participants who performed at chance in at least one priming phase were excluded ($N_{\text{rec}} = 108$; $n_{\text{FMHO}} = 37$, $n_{\text{FMLO}} = 35$, $n_{\text{EE}} = 36$). Recognition accuracy represents proportion of correct responses.

Effect size d for the between-subjects comparisons of the semantic priming effect was calculated as difference of the mean semantic priming effects, divided by the pooled standard deviation of the effects. All other analyses remained the same as in Experiment 1.

Results

Semantic Priming, Day 1

Accuracies in the semantic priming task were above chance in all encoding conditions (all $ps < .001$; see Table 2 for accuracies). Because our main interest was on the semantic priming effects between the FM groups, we first investigated the differences between the semantic priming effects of the FMHO group and the FMLO group. In line with our hypotheses, the semantic priming effect was significantly larger for the FMHO group than for the FMLO group, $t(70) = 1.96$, $p = .027$, $d = 0.46$ (see Figure 5; see Table 2 for response times). There was a significant semantic priming effect in the FMHO condition, $t(36) = 1.72$, $p = .047$, $d = 0.28$, but not in the FMLO condition, $t(34) = -1.07$, $p = .294$, two-tailed, $BF_{01} = 3.27$. The difference between the FMHO and the EE group was not significant, $t(70) = 1.09$, $p = .140$, $BF_{01} = 1.93$. Moreover, no semantic priming effect was found in the EE condition, $t(34) = .32$, $p = .749$, two-tailed, $BF_{01} = 5.25$. If the semantic priming effect after FM encoding was calculated across overlap conditions, no priming effect was found, $t < 1$, two-tailed, $BF_{01} = 7.02$.

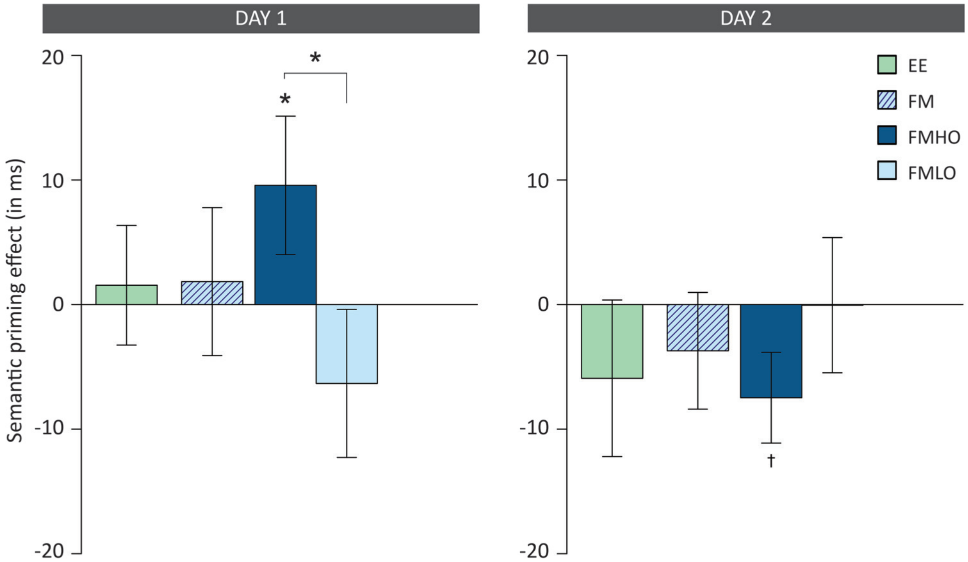
Table 2

Mean Response Times and Mean Accuracies by Relatedness and Encoding Condition in the Semantic Priming Task of Experiment 2, Separately for Day 1 and Day 2

		Day 1			Day 2		
Measure	Encoding condition	Related	Unrelated	Semantic priming effect (unrelated – related)	Related	Unrelated	Semantic priming effect (unrelated – related)
Response times	EE	644.25 (70.14)	645.80 (68.01)	1.55 (28.40)	651.97 (73.65)	646.05 (71.03)	−5.92 (37.16)
	FM (in ms)	647.16 (69.33)	649.00 (62.45)	1.84 (35.15)	629.87 (55.70)	626.16 (50.91)	−3.71 (27.70)
	FMHO	640.63 (75.92)	650.20 (66.16)	9.57 (33.79)	632.42 (53.84)	624.94 (48.71)	−7.48 (22.15)
	FMLO	654.06 (61.97)	647.73 (59.20)	−6.33 (35.17)	627.41 (58.12)	627.35 (53.64)	−0.05 (32.10)
Accuracies	EE	86.07 (8.52)	82.23 (13.24)		86.84 (9.42)	83.00 (11.56)	
	FM (% correct)	83.17 (12.53)	82.48 (10.43)		86.97 (8.92)	86.00 (9.73)	
	FMHO	83.97 (12.19)	83.23 (10.84)		88.14 (8.47)	87.29 (9.51)	
	FMLO	82.37 (12.98)	81.73 (10.10)		85.79 (9.30)	84.72 (9.90)	

Note. Semantic priming effects were calculated as response times for unrelated trials minus response times for related trials. EE = explicit encoding; FM = fast mapping, irrespective of feature overlap; FMHO = fast mapping, high overlap; FMLO = fast mapping, low overlap. Standard deviations in parentheses.

Figure 5
Results of the Semantic Priming Task of Experiment 2 for Day 1 and Day 2



Note. The semantic priming effect was calculated by subtracting response times to related targets from response times to unrelated targets. Error bars represent the standard error of the means. EE = explicit encoding; FM = fast mapping, irrespective of feature overlap; FMHO = fast mapping, high overlap; FMLO = fast mapping, low overlap. † $p < .10$. * $p < .05$. See the online article for the color version of this figure.

Semantic Priming, Day 2

Accuracies in the semantic priming task were above chance in all encoding conditions (all *p*s < .001; see Table 2 for accuracies). The FMHO and FMLO semantic priming effects on Day 2 did not differ, $t(67) = -1.12$, $p = .269$, two-tailed, $BF_{01} = 2.38$, and again, there was no significant priming effect for neither the FMLO group, $BF_{01} = 5.52$, nor the EE group, $BF_{01} = 3.66$, both *t*s < 1, two-tailed. There was a marginally significant negative semantic priming effect for the FMHO group, $t(33) = -1.97$, $p = .057$, two-tailed, $d = 0.39$.

Recognition

In the three-alternative forced-choice recognition test, all groups performed above chance level (all *p*s < .001). As expected, accuracy of the EE group was superior to accuracy of the FM groups, $t(106) = 1.67$, $p = .049$, $d = 0.40$ ($M_{EE} = .52$, $SD_{EE} = .13$; $M_{FM} = .48$, $SD_{FM} = .08$; $M_{FMHO} = .50$, $SD_{FMHO} = .08$; $M_{FMLO} = .47$, $SD_{FMLO} = .08$).[4]

Discussion

In line with our hypotheses, we found a semantic priming effect for the FMHO group on Day 1 but, as suggested by Bayesian statistics, not for the FMLO group. Most importantly, the priming effects in the FMHO group and in the FMLO group were significantly different. This indicates that rapid semantic integration by means of FM is boosted by a high feature overlap between the previously known and the previously unknown item. Although the semantic priming effect for the FMHO group did not significantly differ from the priming effect for the EE group, the Bayes Factor for the semantic priming effect immediately after EE encoding was in favor of the null hypothesis, suggesting that there was no rapid semantic integration after encoding by means of EE.

Whereas not observing a significant priming effect in the FMLO group on Day 2 was in line with our predictions, the expected semantic priming effect for the EE group on Day 2 was not found. It is conceivable that consolidation processes might possibly have been overshadowed by a weakening of the associations overnight. Despite a potential better integration of the associations after 24 hr, retrieval might still have become too effortful after a longer delay, especially considering that, contrary to other studies (e.g., Coutanche & Thompson-Schill, 2014; Greve et al., 2014; Merhav et al., 2014, 2015; Sharon et al., 2011; Warren & Duff, 2014; Warren et al., 2016), participants encoded the associations only once. This is additionally evident in rather weak

[4] Please note that because of a different number of excluded participants for the semantic priming data of Day 1, Day 2, and recognition test data, semantic priming and recognition test results are not necessarily directly comparable. However, if only those participants are included in the recognition test analyses, who were included in the Day 1 semantic priming analyses ($N = 107$), the data pattern remained similar ($M_{FMHO} = .50$, $SD_{FMHO} = .08$; $M_{FMLO} = .47$, $SD_{FMLO} = .08$; $M_{EE} = .52$, $SD_{EE} = .13$), although accuracy of the EE group was only marginally significantly superior to the FM groups, $t(105) = 1.51$, $p = .067$. The pattern was also very similar for a subgroup of those participants who had been included in Day 2 semantic priming analyses ($N = 105$; $M_{FMHO} = .50$, $SD_{FMHO} = .08$; $M_{FMLO} = .47$, $SD_{FMLO} = .08$; $M_{EE} = .52$, $SD_{EE} = .13$) with accuracy of the EE group being superior to the FM groups, $t(103) = 1.68$, $p = .048$. Please note that *M* and *SD* statistics *do* differ but only so slightly that they round up to the same.

recognition accuracy levels (which were also assessed on Day 2), compared with recognition performance typically found in EE learning, which might also be due to more effortful encoding task requirements. Whereas participants are typically only instructed to remember the depicted item in the EE condition, we additionally asked them to answer the same question as in the FM conditions.

Contrary to our expectations, the semantic priming effect for the FMHO group vanished after 24 hr. Previous notions in the literature often emphasize that memories acquired by means of FM are maintained over time, based on the finding that recognition test performance remains above chance even after longer delays (e.g., Coutanche & Thompson-Schill, 2014; Greve et al., 2014; Korenic et al., 2016; Merhav et al., 2015; Sharon et al., 2011; but see Smith et al., 2014). However, it is difficult to draw general conclusions on the robustness of memory representations in FM learning from the present literature. There is a great variety of study–test delays, regarding the duration of the delay (from no delay to a one-week delay), the nature of the filler task and its level of interference (e.g., a vocabulary test: Sharon et al., 2011, and Coutanche & Thompson-Schill, 2014; conversation: Smith et al., 2014, an intelligence test: Greve et al., 2014; math tasks in our experiments), and potential carry-over effects through other (memory) tests that were conducted between the encoding and recognition phase (e.g., free recall of the associations prior to the recognition test, Warren & Duff, 2014, and Warren et al., 2016). In addition, accuracy in explicit forced-choice recognition tests might not be an appropriate measure to investigate robustness in a longitudinal design. Repeated explicit testing within participants inevitably adds noise to measures of neocortical integration and hence, test accuracy no longer represents pure incidental FM learning. Moreover, despite findings of stable memory representations of associations acquired through FM, it has also been suggested that these memories are more fragile than associations acquired through hippocampal-neocortical consolidation processes (e.g., Merhav et al., 2014; Smith et al., 2014; see also Gilboa, 2019). However, our data cannot decide whether we did not find a significant semantic priming effect in the FMHO group on Day 2 because the new memory representations have been lost or because they have been maintained but are more difficult to access. It remains to be further investigated how the memory representations of associations acquired by means of FM develop over time.

Experiment 3

Although Experiment 2 provides evidence for rapid semantic integration in the FMHO condition, it is not yet clear whether the difference between the FMHO and the FMLO condition is attributable to beneficial effects of the discrimination between highly similar items or disturbing effects of the discrimination between dissimilar items. It is conceivable that semantic integration generally benefits from incidental encoding and is inhibited in the FMLO condition, due to the distraction by the low-overlap known item. In particular, a less similar known item might have prevented from processing the unknown item in its exact configuration. To find out whether a high feature overlap in the FMHO condition has an actual beneficial effect, we compared an FMHO condition with a condition in which no object discrimination was required (as only one picture was presented) but a perceptual question still had to be answered (as in the IE condition in Coutanche & Thompson-Schill, 2014, Experiment 2; see Figure 6). Apart from effects of object discrimination, the second aim of Experiment 3 was to investigate the effect of a learning intention on semantic integration through FM. We therefore investigated effects of object discrimination and learning intention using a cross-factorial design. For one group of participants, learning was incidental, and for another group, learning was intentional. Object discrimination was manipulated within subjects in both groups. In particular, in the intentional-learning group, object discrimination was required in an FMHO condition and no object discrimination was required (as only one picture was presented) in an *incidental encoding* (IE) condition. In the intentional-learning group, object discrimination was required in an *intentional FMHO* (intFMHO) condition and no object discrimination was required in a standard EE condition (see also Figure 6).

As we assumed that the discrimination between similar objects is a driving factor for rapid integration through FM, we expected a semantic priming effect for the (incidental) FMHO condition which should be larger than in the EE and IE conditions. Expectations for the intFMHO condition were less straightforward. Even though the intention to learn novel associations might trigger a hippocampal-neocortical pathway to semantic integration, which should not evoke immediate semantic priming effects, it cannot be ruled out that a rapid and direct route to semantic integration might run in parallel in this condition (see also Hebscher et al., 2019).

Method

Participants

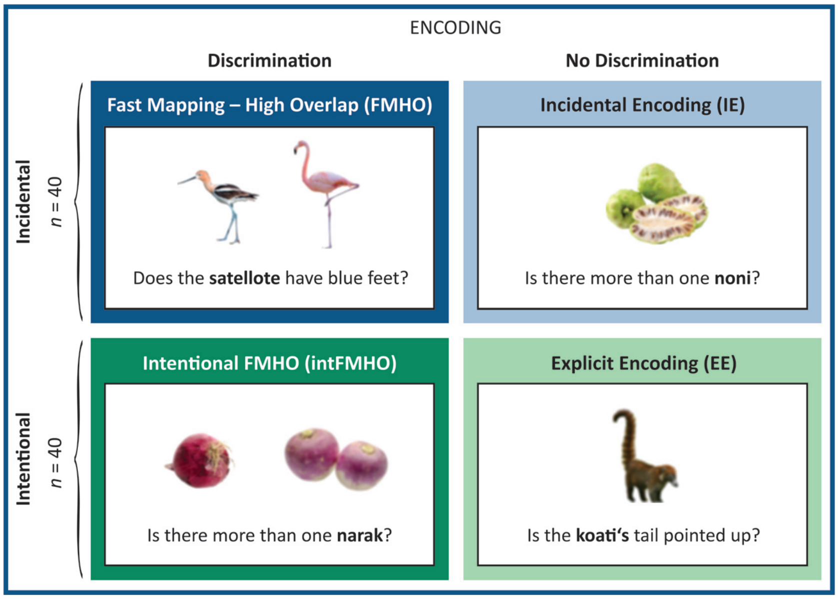
Eighty students from Saarland University were randomly assigned to the group for which learning was incidental and to the group for which learning was intentional. One participant of the incidental learning group had to be excluded because he had already taken part in another experiment in which the same stimulus material was used, resulting in an overall sample size of $N = 79$ participants ($n_{\text{intentional}} = 40$, $n_{\text{incidental}} = 39$; 59 female: 33 in the intentional group, 26 in the incidental group; $M_{\text{age}} = 22.7$ years, age range: 18–30 years). There was no age difference between groups, $t < 1$.

Materials

Encoding. Of 96 pictures (arranged in 48 item pairs) drawn from the same item pool as in Experiment 1, the 48 unknown items had been rated as unknown by 93% ($SD = 5\%$) of the participants in the rating study and had been given mean familiarity ratings of $M = 1.82$ ($SD = 0.34$). The 48 previously known pictures had been rated as known by 94% ($SD = 7\%$) of the participants in the rating study and had been given familiarity ratings of $M = 4.50$ ($SD = 0.29$). Feature overlap had been rated as $M = 3.66$ ($SD = 0.30$). The unknown items' labels were created in the same manner as in Experiment 2 and consisted of four to 10 letters with a mean length of $M = 6.48$ letters ($SD = 1.27$).

Semantic Priming. As in Experiment 2, the previously unknown items were used as primes, and targets were either animals or plants. Overall, 96 different targets were presented, which were chosen to be preferably long (3–16 letters; $M = 8.34$, $SD = 2.17$) while at the same time keeping their lemma frequencies as low as possible (between 0.01 and 3.08 per million

Figure 6
Design of the Encoding Phase in Experiment 3



Note. Learning intention was manipulated between subjects (blue = incidental learning group, green = intentional learning group), object discrimination within subjects (order of conditions counterbalanced between subjects, see main text). The procedure of the semantic priming and recognition test phases was analogous to Experiment 2. FMHO = fast mapping, high overlap; intFMHO = intentional fast mapping, high overlap. See the online article for the color version of this figure.

words; M = 0.53, SD = 0.51; Heister et al., 2011). Each target was presented twice, once together with a related prime and once together with an unrelated prime. Each prime appeared four times (once in each of four priming blocks), twice together with a related target and twice with an unrelated target (order counterbalanced, i.e., either related–unrelated–unrelated–related or unrelated–related–related–unrelated). The targets were not presented elsewhere in the experiment.

Recognition. Recognition test materials were created as in Experiment 2.

Design and Procedure

Encoding. Half of the participants encoded the items intentionally. They were informed about the memory test exactly as the EE group in Experiment 2. The other half of the participants encoded the items incidentally, using the same cover story as in Experiments 1 and 2. The remaining procedure of the experiment was exactly the same for both groups. Both groups encoded the 48 items in four blocks of 12 trials each (plus additional four condition-matched filler trials in each block, one inserted at the beginning and one at the end of each block), of which two blocks consisted of the respective *discrimination* condition (incidental group: FMHO, intentional group: intFMHO) and two blocks consisted of the *no-discrimination* condition (incidental group: IE, intentional group: EE). Hence, the intentional-learning group completed two intFMHO blocks and two EE blocks (order counterbalanced, i.e., either intFMHO–EE–EE–intFMHO or EE–intFMHO–intFMHO–EE) and the incidental-encoding group completed two FMHO blocks and two IE blocks (order counterbalanced, i.e., either FMHO–IE–IE–FMHO or IE–FMHO–FMHO–IE). In the discrimination conditions (i.e., FMHO and intFMHO), two pictures were presented above the question (left and right of the center of the screen), one of which was previously unknown and one was previously known (see Figure 6). In the no-discrimination conditions (i.e., IE and EE), only one picture was presented above the question in the center of the screen (see Figure 6). The four encoding blocks were separated by 30-s breaks in which participants were informed that in the next block, they would be presented with either one picture (IE and EE conditions) or two pictures (FMHO and intFMHO conditions). Participants completed a practice phase before the encoding phase that consisted of two blocks of six trials (each including two filler trials) in which they were presented with only one picture in the first block and with two pictures in the second block or vice versa (order counterbalanced between participants). Analogously to the actual encoding phase, practice blocks were separated by a short break in which they were informed if one or two pictures would be presented in the next block. Everything else of the encoding procedure was as in Experiments 1 and 2.

Semantic Priming. After the four-minute retention interval, the semantic priming task was administered. Each trial started with the presentation of a fixation cross in the center of the screen for 700 ms, followed by the prime word for 300 ms. After the prime had disappeared, a blank screen was displayed for 250 ms, which was then replaced by the target word. Response requirements were as in Experiment 2. The whole priming phase was arranged in four blocks that were separated by a one-minute break in which participants could rest. Thus, the priming phase comprised 192 trials with 48 trials in each block. Within a block, each prime was presented once and trials were presented in random order. Each target appeared twice in the priming phase, either in the first and third block or in the second and fourth block. Two buffer trials (using pseudowords as primes) were inserted at the beginning of each priming block to accustom participants to the fast pace of the task. Prior to the priming phase, participants were familiarized with the priming paradigm in a 6-trial practice phase similar to that of Experiment 2.

Recognition and Rating of Previous Knowledge. The procedures of the recognition test and the rating of previous knowledge were as in Experiment 2.

Data Analyses

The calculation of semantic priming effects and outlier analyses were as in Experiment 2. On average, 11.39% of correct trials were excluded because the individual rating of previous knowledge for at least one of the two items of the encoding screen was incongruent with the expected knowledge. Excluding individual outlier data points with regard to response latencies resulted in a final mean dropout rate of 13.59% of correct trials. Sixteen outlier participants with regard to the semantic priming effect were removed from the analyses (incidental group: 7; intentional group: 9), which resulted in a final sample size of $n = 32$ participants in the incidental learning group (i.e., FMHO and IE conditions) and $n = 31$ participants in the intentional learning group (i.e., intFMHO and EE conditions) for the semantic priming analyses. No participants had to be removed for chance performance in the semantic priming task. Eight participants had to be excluded from the recognition analyses for list errors (incidental group: 5; intentional group: 3). The factor object discrimination was included as within-subjects factor in all models, with the levels *discrimination* and *no discrimination*. The factor learning intention was included as between-subjects factor with the levels *intentional* and *incidental*. If the criterion of homogeneity of variances between groups was not fulfilled, t test statistics were reported according to Welch's modification to degrees of freedom. Effect size η_p^2 reflects the ratio of the sum of squares of the effect to the sum of squares associated with the effect plus the residual sum of squares.

Results

Semantic Priming

Accuracies in the semantic priming task were above chance in all conditions (all $ps < .001$) and separately for all subjects ($p < .05$, binomial test). To investigate the effects of the factors object discrimination and learning intention, a 2 × 2 factorial mixed ANOVA was conducted, revealing a main effect of learning intention, $F(1, 61) = 5.09$, $p = .028$, $\eta_p^2 = .22$, with greater priming effects for incidental compared with intentional learning (see Table 3). Neither the main effect of object discrimination was significant, $F(1, 61) = 1.95$, $p = .168$, $BF_{01} = 2.29$, nor the Object Discrimination × Learning Intention interaction, $F(1, 61) = 2.41$, $p = .125$, $BF_{01} = 1.37$. As hypothesized, the semantic priming effect in the incidental-learning group was significantly larger in the FMHO condition than in the IE condition, $t(31) = 1.98$, $p = .029$, $d = 0.41$ (see Table 3 for descriptive statistics). Comparing the object-discrimination conditions (between groups), the semantic priming effect was larger for the FMHO condition compared with the intFMHO condition, $t(47.78) = 2.27$, $p = .028$, $d = 0.57$, two-tailed. In addition, the semantic priming effect for the FMHO condition was larger than the effect for the EE condition, $t(38.38) = 2.37$, $p = .012$, $d = 0.59$. Importantly, the findings of Experiment 2 were replicated, that is, there was a significant semantic priming effect for the FMHO condition, $t(31) = 2.21$, $p = .017$, $d = 0.39$, but not for the EE condition, $t < 1$, two-tailed, $BF_{01} = 3.77$. There was neither a significant priming effect in the IE condition, $t(31) = 1.48$, $p = .149$, $d = 0.26$, $BF_{01} = 1.98$, nor in the intFMHO condition, $t < 1$, $BF_{01} = 4.19$, both two-tailed (see Figure 7). As the IE condition showed a numerical tendency toward a priming effect, we conducted additional exploratory post hoc analyses. These showed that in the IE condition, the semantic priming effect was marginally significantly affected by the order of the encoding conditions, $t(19.98) = -1.98$, $p = .062$, $d = 0.26$, two-tailed. There was a tendency that the priming effect was slightly larger for participants who started the encoding phase with the FMHO condition, and thus, the IE condition had been preceded by the FMHO condition, compared with the IE priming effect for participants who started with the IE condition.

Recognition

There were no significant differences in recognition accuracy between encoding conditions, with neither a main effect of

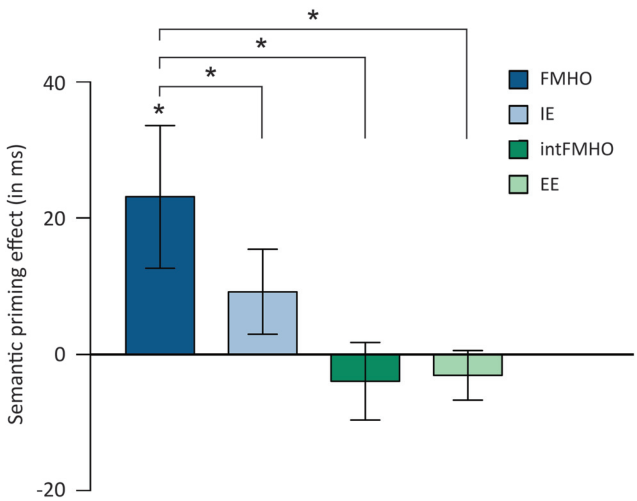
Table 3

Mean Response Times and Mean Accuracies by Relatedness and Encoding Condition in the Semantic Priming Task of Experiment 3

Measure	Learning intention	Encoding condition	Related	Unrelated	Semantic priming effect (unrelated – related)
Response times (in ms)	incidental	FMHO	638.85 (57.49)	661.97 (92.71)	23.11 (59.13)
		IE	651.60 (78.24)	660.79 (86.59)	9.19 (35.17)
	intentional	intFMHO	643.72 (73.12)	639.79 (79.11)	−3.93 (31.71)
		EE	646.91 (77.60)	643.84 (72.50)	−3.06 (20.25)
Accuracies (in % correct)	incidental	FMHO	91.69 (53.10)	90.77 (53.78)	
		IE	90.99 (54.52)	89.11 (68.79)	
	intentional	intFMHO	90.48 (73.44)	90.61 (73.97)	
		EE	90.87 (79.18)	91.68 (63.95)	

Note. Semantic priming effects were calculated as response times for unrelated trials minus response times for related trials. FMHO = fast mapping, high overlap; IE = incidental encoding; intFMHO = intentional fast mapping, high overlap; EE = explicit encoding. Standard deviations in parentheses.

Figure 7
Results of the Semantic Priming Task of Experiment 3



Note. FMHO = fast mapping, high overlap; IE = incidental encoding; intFMHO = intentional fast mapping, high overlap; EE = explicit encoding. Error bars represent the standard error of the mean. * $p < .05$. See the online article for the color version of this figure.

learning intention, $F(1, 69) = 1.03$, $p = .313$, $BF_{01} = 2.81$, nor an effect of object discrimination, $F < 1$, $BF_{01} = 4.36$, nor their interaction, $F < 1$, $BF_{01} = 4.51$($M_{FMHO} = .47$, $SD_{FMHO} = .13$; $M_{IE} = .48$, $SD_{IE} = .14$; $M_{intFMHO} = .49$, $SD_{intFMHO} = .16$; $M_{EE} = .51$, $SD_{EE} = .14$), but accuracy was above chance level for all groups, all *p*s < .001.[5]

Discussion

In line with our hypothesis, we found a larger semantic priming effect when both object discrimination was required and learning was incidental compared with when no object discrimination was required (irrespective of learning intention). Moreover, the effect in the (incidental) FMHO condition was also larger than in the intentional FMHO (intFMHO) condition. In addition, the results of Experiment 2 were replicated, that is, rapid semantic integration was found in the (incidental) FMHO condition but not in the EE condition. These results indicate that rapid semantic integration is boosted by incidental encoding and by the discrimination of similar objects during encoding.

Although rapid semantic integration was observed in the FMHO condition (thereby replicating the finding of Experiment 2), the results are not clear-cut with respect to the effect of discrimination. One could raise the concern that the main effect of object discrimination and the Object Discrimination × Learning Intention interaction did not reach significance only because there was an unexpected numerical tendency toward a semantic priming effect in the IE condition. Because this might be caused by carry-over effects by the preceding FMHO condition in some participants, we compared the FMHO and IE conditions again in Experiment 4 using a between-subjects design by which we could exclude any order effects in the IE condition and clarify the debatable results of Experiment 3.

Experiment 4

In contrast to Experiment 3, encoding was always incidental in Experiment 4 and object discrimination was manipulated between subjects. Following the idea that higher demands on object discrimination lead to better semantic integration in FM learning, it was expected that larger semantic priming effects should be found after encoding in the FMHO condition, in which object discrimination was demanding, compared with the IE condition, in which no object discrimination was required.

Method

Participants

Eighty students from Saarland University were randomly allocated to one of two encoding conditions (FMHO, IE), in which encoding was always incidental ($n_{FMHO} = 40$, $n_{IE} = 40$; 56 female: 30 in the FMHO condition, 26 in the IE condition; $M_{age} = 21.63$, age range: 18–29 years). There was no age difference between groups, $t < 1$.

Materials

Stimulus material of Experiment 4 was the same as in Experiment 3.

Design and Procedure

Encoding. As object discrimination was manipulated between subjects, all trials were encoded within a single encoding block. Half of the participants were always presented with one picture at a time (IE) and the other half was presented with two pictures (FMHO). Everything else was as in Experiment 3.

Filler Task, Semantic Priming, Recognition, and Rating of Previous Knowledge. Design and procedure of these tasks was the same for both experimental groups and did not differ from Experiment 3.

Data Analyses

The computation of the semantic priming effects, outlier exclusion, and the exclusion of trials attributable to incongruence of the individual knowledge with the expected knowledge was the same as in Experiment 3. The exclusion of knowledge-incongruent trials resulted in a mean dropout rate of 16.46% of correct trials per participant. After the exclusion of individual outlier trials with regard to response latencies, the final mean dropout rate for the analyses was 19.05% of correct trials. Three participants were excluded from the semantic priming analyses because they were outliers with regard to the semantic priming effect for their group, two in

[5] Please note that owing to a different number of excluded participants for the semantic priming data and the recognition test data, semantic priming and recognition test results are not necessarily directly comparable. In addition, eight participants were excluded from the recognition dataset because of a list error. However, if only those participants are included in the recognition test analyses who were included in the semantic priming analyses and if participants with list errors remained included (and trials potentially affected by list errors were removed), the data pattern remained similar (i.e., $M_{FMHO} = .47$, $SD_{FMHO} = .13$; $M_{IE} = .48$, $SD_{IE} = .15$; $M_{intFMHO} = .47$, $SD_{intFMHO} = .17$; $M_{EE} = .49$, $SD_{EE} = 14$; neither a main effect of learning intention, nor object discrimination, nor their interaction, all *F*s < 1).

Table 4
Mean Response Times and Mean Accuracies by Relatedness and Encoding Condition in the Semantic Priming Task of Experiment 4

Measure	Encoding condition	Related	Unrelated	Semantic priming effect (unrelated – related)
Response times (in ms)	FMHO	619.05 (50.14)	623.05 (48.72)	4.01 (11.45)
	IE	628.80 (48.79)	627.14 (50.60)	−1.66 (13.99)
Accuracies (in % correct)	FMHO	88.11 (32.37)	88.57 (31.82)	
	IE	89.65 (30.47)	90.16 (29.79)	

Note. Semantic priming effects were calculated as response times for unrelated trials minus response times for related trials. FMHO = fast mapping, high overlap; IE = incidental encoding. Standard deviations in parentheses.

the FMHO group and one in the IE group, resulting in a final sample size of $N = 77$ ($n_{\mathrm{FMHO}} = 38$, $n_{\mathrm{IE}} = 39$). No participants had to be removed for chance performance in the semantic priming task. Everything else was as in Experiment 3.

Results

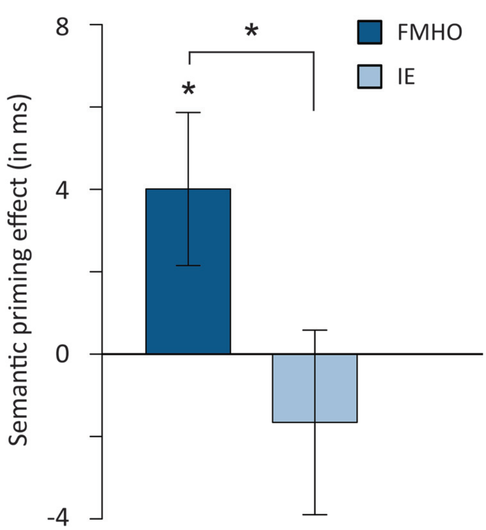
Semantic Priming

All participants performed above chance in the semantic priming task; see Table 4 for mean accuracies). In line with our hypothesis and the results of Experiment 3, semantic priming effects between the FMHO and the IE group were significantly different, $t(75) = 1.94$, $p = .028$, $d = 0.44$. As expected, there was a significant semantic priming effect for the FMHO group, $t(37) = 2.16$, $p = .019$, $d = 0.35$, and no priming effect was found for the IE group, $t < 1$, two-tailed, $\mathrm{BF}_{01} = 4.49$ (see Figure 8; see Table 4 for mean response times).

Recognition

Participants recognized the associations above chance level in both the FMHO group ($M = .45$, $SD = .09$) and the IE group ($M = .45$, $SD = .12$), both $ps < .001$. Recognition accuracy did not differ between groups, $t < 1$, two-tailed, $\mathrm{BF}_{01} = 4.27$.[6]

Figure 8
Results of the Semantic Priming Task of Experiment 4



Note. FMHO = fast mapping, high overlap; IE = incidental encoding. Error bars represent the standard error of the mean. * $p < .05$. See the online article for the color version of this figure.

Discussion

As expected, there was a significant effect of object discrimination, with a greater semantic priming effect for the FMHO group compared with the IE group. In Experiment 4, the Bayes Factor suggested more clearly to favor the null model for the semantic priming effect in the IE condition, indicating that no rapid semantic integration occurred if no discrimination was required. Thus, the results of Experiment 4 are analogous to Experiment 2, where a larger immediate priming effect was found when the demands on object discrimination were high compared with when they were low (operationalized by differential feature overlap). This further supports the idea that the difference of semantic priming effects between the FMHO and FMLO condition is based on beneficial effects of a high feature overlap in the FMHO condition and not on detrimental effects of low feature overlap.

General Discussion

It has been proposed that fast mapping (FM) might be a learning paradigm that allows for rapid, direct integration of novel associations into cortical memory networks (e.g., Atir-Sharon et al., 2015; Coutanche & Thompson-Schill, 2014; Himmer et al., 2017; Merhav et al., 2014, 2015; Sharon et al., 2011). Yet, contradictory findings have been reported (e.g., Greve et al., 2014; Smith et al., 2014; Warren & Duff, 2014; Warren et al., 2016), and it has been unclear which factors could possibly moderate rapid semantic integration through FM. We approached this issue from a neurocognitive perspective. Because of its functional and representational characteristics, the PrC is especially qualified for the discrimination between complex objects (see, e.g., Barense et al., 2005; Bussey et al., 2002, 2005; Cowell et al., 2010), which is an essential cognitive operation in the FM task. Across four behavioral experiments, we therefore tested the assumption that rapid, direct cortical integration through FM benefits from conditions presumably enhancing PrC engagement. In order to do so, we aimed to vary specifically the demands on perirhinal processing during FM encoding by comparing rapid cortical integration in a condition in which the demands on object discrimination were high, that is, the

[6] If only those participants are included in the recognition test analyses who were included in the semantic priming analyses, the data pattern remained the same (i.e., $M_{\mathrm{FMHO}} = .45$, $SD_{\mathrm{FMHO}} = .09$; $M_{\mathrm{IE}} = .45$, $SD_{\mathrm{IE}} = .12$; accuracy difference between groups, $t < 1$). Please note that M and SD statistics *do* differ but only so slightly that they round up to the same.

unknown and the known item in the encoding display were highly similar (fast mapping, high overlap; FMHO), with a condition in which the demands on object discrimination were low, that is, the items only shared few features (fast mapping, low overlap; FMLO). To assess cortical integration, we made use of indirect measures, namely lexical competition and semantic priming. In Experiment 1, we did not find an advantage of a high feature overlap when cortical integration was captured by a lexical competition task. However, we observed a general lexical competition effect across feature overlap conditions, indicating that lexical integration by means of FM is generally possible. This is also consistent with the findings by Coutanche and Thompson-Schill (2014), who additionally showed that lexical integration was only found for an FM condition but neither for an explicit encoding (EE) condition nor for incidental encoding per se. Thus, rapid lexical integration of the label through FM seems to be possible irrespective of the demands on object discrimination. Accordingly, we suggest that lexical integration of the label on an item level does not presuppose the integration of the association between the label *and the picture* and therefore does not benefit from higher demands on the discrimination between the *pictures* of the known and unknown item. This seems to be different for semantic integration of the label, for which the FMHO condition was indeed beneficial compared with the FMLO condition (Experiment 2). Moreover, rapid semantic integration in the FMHO condition was also found to be enhanced compared with an EE condition (Experiment 3) and compared with a condition in which no object discrimination was required at all (incidental encoding, IE; Experiments 3 and 4). This is in line with our assumption that stronger PrC involvement in the FMHO condition fosters rapid integration through FM, which is also further supported by recent fMRI evidence of our own lab (Zaiser et al., 2020), showing stronger PrC activation at encoding and greater PrC contribution to learning in an FMHO condition compared with an FMLO condition. This also corresponds to a study in 18- to 24-month-old children that showed better memory for novel words learned in a fast mapping paradigm when discrimination during learning was more ambiguous, that is, when the known item had been acquired only recently compared with when the known item was highly familiar (Kucker et al., 2020). In Experiment 3, we additionally tested whether changing the FM paradigm from an incidental to an intentional task would diminish the beneficial effects of a high feature overlap in the FM encoding display, which was indeed the case. Thus, likely triggering the hippocampal-neocortical pathway (as intended through the intentional learning instructions) seems to hamper rapid semantic integration through FM.

When we manipulated the demands on object discrimination, we intended to vary perceptual feature overlap between the previously known and the previously unknown item. However, with our stimulus materials, perceptual and semantic overlap were conflated as perceptually similar items also shared many semantic features. Thus, the FMHO group might not only have benefited from higher demands on perceptual discrimination but also from higher demands on semantic discrimination and possibly facilitated integration into semantic networks owing to the availability of a semantically similar known item (see also Mak, 2019). So far, it is unclear whether semantic or perceptual similarity of the pictures is the crucial factor that boosts rapid cortical integration through FM. We can imagine that both are beneficial but for different cognitive operations. A demanding discrimination between both perceptually and semantically similar pictures might be important to initially trigger PrC processing (see e.g., Martin et al., 2018), whereas specifically the increase in semantic overlap might possibly facilitate (ATL-mediated) semantic integration (see, e.g., Lambon Ralph et al., 2017). The assumption of a facilitatory effect on semantic integration through a high semantic similarity between the known and the unknown item in the FMHO condition intuitively seems at odds with the results recently reported by Coutanche and Koch (2017), showing that especially atypical known items are beneficial for lexical integration of the labels. However, although typicality of the known item and semantic similarity between the unknown and the known item might often be related, feature overlap in our experiments was not confounded with typicality as exactly the same known items were used in both groups. This indicates that a high feature overlap supports rapid semantic integration through FM, irrespective of the typicality of the known item.

Our suggestion that higher demands on the discrimination between pictures are eventually beneficial for rapid semantic integration through FM can explain how the *pictures* of the unknown items can be semantically integrated. However, this is not sufficient to explain why we observed rapid semantic integration of the *labels* (Experiments 2–4), which did not have any semantic connotations before. To explain the rapid integration of the labels into semantic memory networks, the process by which the label is *bound* to the semantic information provided by the picture needs to be addressed. Beside its involvement in object discrimination, the PrC is also involved in the binding of an item's elemental features to a coherent feature conjunction (Barense et al., 2005; Barense et al., 2007; Cowell et al., 2006). Therefore, we can imagine that once perirhinal processing is triggered through high demands on object discrimination (i.e., a high perceptual and/or semantic feature overlap) in the FMHO condition, the picture of the unknown item and the label might be bound to an intraitem association or unit by means of perirhinal binding mechanisms (see, e.g., Haskins et al., 2008). This unit can then be directly semantically integrated, which might be facilitated by the presentation of a semantically similar known item, as suggested above. Such direct semantic integration through perirhinal binding mechanisms might be possible without hippocampal involvement (see, e.g., Sharon et al., 2011).

Although learning was incidental in the FM paradigm used by Sharon et al. (2011), which was beneficial for patients with lesions predominantly to the hippocampus, the intention to learn had not been manipulated in previous FM experiments. Experiment 3 revealed that the intention to learn, by which hippocampal binding mechanisms should be triggered, hampers rapid semantic integration though FM in young and healthy adults, in whom both the slow hippocampal-neocortical and the rapid and direct route to semantic integration should generally be available. It is thus conceivable that in an intentional FMHO (intFMHO) condition, hippocampal relational binding mechanisms might have provoked a slow, hippocampal-neocortical route to semantic integration. This further suggests that within an FM paradigm, the potential activation of a slow, presumably hippocampal route to semantic integration could overshadow a rapid and direct pathway and speaks against the idea that both routes to cortical integration work in parallel (cf. Hebscher et al., 2019; see also Cooper et al., 2018). Possible candidate mechanisms for overshadowing could be direct inhibition of cortical integration by hippocampal output and/or competition between hippocampal and extrahippocampal systems (Sutherland et al., 2010). Nevertheless, it can be said that the main effect of learning intention in Experiment 3, together with the Bayes Factor supporting the null hypothesis that there is no semantic priming effect in the intFMHO condition, even though object discrimination was required, indicate that incidental learning seems to be a driving factor for successful rapid semantic integration through FM, as was suggested by Sharon et al. (2011).

It has been noted previously that associations acquired by means of FM seem to be stable over time because it has been found that recognition test performance remains above chance level even after longer delays (e.g., Coutanche & Thompson-Schill, 2014; Greve et al., 2014; Korenic et al., 2016; Merhav et al., 2015; Sharon et al., 2011; but see Smith et al., 2014). However, this assumption is not supported by the findings of Experiment 2, in which Bayesian analyses suggest that no significant semantic priming effect was observed after a 24-hr delay. It cannot finally be said why, in the FMHO condition, the labels that had already been rapidly semantically integrated (as reflected by an immediate semantic priming effect) did not provoke a semantic priming effect after a 24-hr delay. One possible explanation, however, is that the associations had only been weakly integrated. The absence of consolidation processes overnight (see e.g., Himmer et al., 2017; Merhav et al., 2015) might possibly have led to a further weakening of the links to other nodes in the semantic networks during the following 24 hr. Such a weak semantic integration could partly be based on interference associated with the large number of trials (see Merhav et al., 2014; see also Gilboa, 2019), which was higher in our experiments than in most FM experiments (92 trials in Experiment 1 and 48 trials in Experiments 2–4, instead of 16–24 trials per encoding condition, as in, e.g., Coutanche & Thompson-Schill, 2014; Greve et al., 2014; Sharon et al., 2011; but see also Merhav et al., 2015; who used 50 trials per encoding condition). Moreover, using more trials makes it difficult to provide a stimulus list consisting of heterogeneous materials and homogeneity of the stimulus material could have further increased this interference, especially for unfamiliar items (see Brandt et al., 2019). This post hoc explanation that an initially weak or fragile integration might underlie the absence of a semantic priming effect on Day 2 would also be in line with the assumption that associations acquired through FM might remain in a "hypothetical status" and can easily be overwritten (see, e.g., Gilboa, 2019; Merhav et al., 2014). This notion dovetails with findings suggesting that adults and children build hypothesized label-object associations in situations in which multiple mappings are possible (Trueswell et al., 2013; Woodard et al., 2016). Based on their "Propose-but-Verify" framework, Trueswell et al. (2013) suggest that in subsequent learning situations with the same label, such associations are then either confirmed or revised. Apart from that, other characteristics of our experimental procedures might have been disadvantageous for a stronger initial integration. For instance, questions were only presented visually instead of bimodally as in other FM studies (e.g., Greve et al., 2014; Merhav et al., 2014; Sharon et al., 2011; Smith et al., 2014) and, also in contrast to other studies (see above), each association was encoded only once. Nevertheless, we think such a single-exposure encoding procedure is suited best to investigate differential effects between encoding conditions. In that way, they can clearly be attributed to differences in pure encoding processes and cannot be influenced by retrieval processes during repeated presentations at encoding. It is noticeable, however, that our experiments clearly revealed that immediate integration of novel associations through FM is possible, *despite* relatively high numbers of trials and, most importantly, even after only a single exposure to the associations.

Apart from modulating effects of feature overlap and learning intention on rapid semantic integration through FM, a high feature overlap was not beneficial for rapid lexical integration in Experiment 1. However, the lexical competition effect that we observed across overlap conditions suggests that in general, rapid lexical integration on an item level seems possible by means of FM, which also replicates the findings by Coutanche and Thompson-Schill (2014). It remains to be further examined what exactly drove general lexical integration through FM in Experiment 1. The findings by Coutanche and Thompson-Schill (2014, Experiment 2) indicate that the presence of a previously known item is required for rapid lexical integration. One could conclude from their results that, generally, a semantically enriched learning situation is beneficial for lexical integration. Our Experiment 1 results further suggest that this might be the case irrespective of feature overlap. However, Experiment 2 indicates that a generally semantically enriched environment is not sufficient for the integration of a label together with semantic information. In line with this, paradigms within which both lexical and semantic integration can be tested simultaneously show that cortical integration of semantic information seems to require a time-consuming consolidation process (i.e., 1 week without further practice) whereas the integration of the pure word forms on a lexical level can be completed rapidly after encoding even in standard intentional learning paradigms (Clay et al., 2007). When novel labels were encoded without a semantic context, however, Gaskell and Dumay (2003) found lexical integration (i.e., lexical competition effects) only after a delay of 5–8 days. Thus, whereas generally a semantic context might promote the first step required in word learning, namely the integration of the label, further integration into semantic networks might be facilitated by multimodal object integration within the PrC. Nevertheless, one needs to be cautious when relating the results of Experiment 1 to those of Experiments 2–4 directly because differences in the task and design (i.e., within vs. between subjects) preclude definite conclusions. Further research is needed to shed light on the mechanisms underlying rapid *lexical* integration of the label on an item level in the FM paradigm and how this relates to factors driving rapid *semantic* integration that we identified in Experiments 2–4.

It has recently been extensively discussed whether the FM phenomenon exists at all (see Cooper et al., 2018, and the respective commentaries). To our understanding, the aim of research on FM is not to show that learning through FM is a completely new mechanism that is distinct from any other learning mechanisms. We suggest that it should be considered what it is, that is, an encoding paradigm that may trigger the mechanisms necessary to enable rapid cortical integration of novel, arbitrary associations. Within four experiments, we aimed to identify factors which might be able to resolve contradictory findings in the literature and shed further light on why rapid cortical integration was found in patient studies such as

Sharon et al. (2011). Analogously to the beneficial effects of a high feature overlap and incidental encoding for rapid semantic integration through FM in healthy young adults, the same factors might have driven above-chance recognition performance in patients with severe hippocampal lesions in the study by Sharon et al. (2011), especially because feature overlap in this study seems to have been high (see also Sharon, 2010). We consider it conceivable that a rapid and direct route to cortical semantic integration might possibly be triggered through a high feature overlap and incidental encoding in at least a similar manner for healthy adults and individuals who cannot rely on hippocampal functioning. However, further experiments designed from a neurocognitive perspective are necessary for a better understanding.

Conclusions

The present findings contribute to the resolution of contradictions in the literature on the FM paradigm as we identified factors modulating rapid semantic integration by means of FM. Whereas lexical integration of the labels was unaffected by feature overlap in the FM encoding phase, rapid semantic integration requires that the pictures of the known and the unknown item need to share many features. In addition, it was found that incidental learning is a driving factor for rapid semantic integration through FM. We offered suggestions on the mechanisms possibly underlying rapid cortical integration of associations encoded within the FM paradigm, which yet need to be confirmed by further research.

Context

There is an ongoing debate about whether rapid integration of novel associations through fast mapping (FM) is possible as contradictory findings have been reported (see Cooper et al., 2018; and the corresponding commentaries). To resolve these contradictions, we set out to find factors moderating rapid cortical integration through FM from a neurofunctional perspective, suggesting that the functional and representational characteristics of the perirhinal cortex might be especially qualified to contribute to rapid semantic integration through FM (see Zaiser et al., 2019; Zaiser et al., 2020). This research is closely related to previous work by the authors on binding mechanisms in memory which might recruit a similar network (i.e., unitization; e.g., Bader et al., 2010; Bader et al., 2014) and the role of medial temporal lobe structures in semantic processing (e.g., Meyer et al., 2005; Meyer et al., 2010; Meyer et al., 2013).

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Appendix A

Newly Created Lexical Neighbors to German Hermit Words, Used as Labels in Experiment 1 to Evoke Lexical Competition

Neighbor	Hermit	Translation	Neighbor	Hermit	Translation
Akroyat	Akrobat	acrobat	Matralle	Matratze	mattress
Albur	Album	album	Menka	Mensa	canteen
Borbe	Bombe	bomb	Minuster	Minister	minister
Brude	Bruder	brother	Mored	Moped	moped
Dontor	Doktor	doctor	Murtel	Murmel	marble
Eigel	Eigelb	egg yolk	Muspel	Muskel	muscle
Fabrek	Fabrik	factory	Orfel	Orgel	pipe organ
Famolie	Familie	family	Palist	Palast	palace
Flemme	Flamme	flame	Pfalle	Pfanne	pan
Förser	Förster	forester	Pilor	Pilot	pilot
Futo	Foto	photo	Pistoke	Pistole	pistol
Galanie	Galaxie	galaxy	Plakal	Plakat	placard
Globuk	Globus	globus	Satellot	Satellit	satellite
Gürmel	Gürtel	belt	Schirk	Schirm	umbrella
Honil	Honig	honey	Schneel	Schnee	snow
Kaisek	Kaiser	emperor	Stiemel	Stiefel	boot
Kalunder	Kalender	calendar	Taifur	Taifun	typhoon
Keramuk	Keramik	ceramic	Torado	Tornado	tornado
Kleiser	Kleister	paste	Trator	Traktor	tractor
Knoske	Knospe	bud	Trelor	Tresor	safe
Kondimor	Konditor	confectioner	Trochel	Trommel	drum
Künsler	Künstler	artist	Tunnek	Tunnel	tunnel
Lössel	Löffel	spoon	Tursine	Turbine	turbine
Magalin	Magazin	magazine	Vulka	Vulkan	volcano

Note. Participants were explicitly instructed to categorize persons or professions as *natural*. In the encoding phase, one third of the hermit neighbors were presented as labels in the FMHO (fast mapping, high overlap) condition, one third in the FMLO (fast mapping, low overlap) condition, and one third were not encoded, as in the lexical competition task, the respective hermit words served as nonneighbor hermits (i.e., hermit words which did not obtain a new neighbor at encoding).

(*Appendices continue*)

Appendix B

Schematic Depiction of the Construction of Stimulus Lists of the Lexical Competition Task in Experiment 1

			Participant 1		Participant 2		Participant 3	
Hermit neighborhood at test	Overlap at Encoding	Real Name	Encoding Label	Test Target	Encoding Label	Test Target	Encoding Label	Test Target
Neighbor hermit 1	FMHO	Koati	Trator	Traktor	Palist	Palast	Satellot	Satellit
Neighbor hermit 2	FMHO	Booby	Dontor	Doktor	Knoske	Knospe	Pfalle	Pfanne
Neighbor hermit . . .	FMHO	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Neighbor hermit 16	FMHO	Takahe	Magalin	Magazin	Albur	Album	Flemme	Flamme
Neighbor hermit 17	FMLO	Avocet	Satellot	Satellit	Trator	Traktor	Palist	Palast
Neighbor hermit 18	FMLO	Mungo	Pfalle	Pfanne	Dontor	Doktor	Knoske	Knospe
Neighbor hermit . . .	FMLO	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Neighbor hermit 32	FMLO	Goura	Flemme	Flamme	Magalin	Magazin	Albur	Album
Nonneighbor hermit 1	Not encoded	—		Palast		Satellit		Traktor
Nonneighbor hermit 2	Not encoded	—		Knospe		Pfanne		Doktor
. . .	Not encoded	—		. . .		. . .		. . .
Nonneighbor hermit 16	Not encoded	—		Album		Flamme		Magazin

Note. In the lexical competition task, each participant was presented with 48 test targets, which were all hermit words, that is, they did not have a lexical neighbor prior to the experiment. Thirty-two of these hermits had obtained a new neighbor at encoding (i.e., a picture of an unknown item had been presented together with a label that is a (new) lexical neighbor to a hermit word) and were thus called *neighbor hermits* (e.g., for Participant 1, the avocet was called *satellote* at encoding, which is a new neighbor to the test target *satellite*). Of these 32 neighbor hermit test targets, 16 had been encoded in the FMHO condition and 16 in the FMLO condition. For the remaining 16 test targets, no newly created lexical neighbors had been presented at encoding, which is why they were named *nonneighbor hermits* (lower third of the table). The assignment of item names (and thus, test targets) was counterbalanced between subjects. Please note that FMHO neighbor hermits, FMLO neighbor hermits, and nonneighbor hermits are depicted in blocks here only for schematic simplification. Trials in the actual lexical competition task were presented in random order. FMHO = fast mapping, high overlap; FMLO = fast mapping, low overlap.

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