Evidence of Animacy Effects in Novel Word Learning via Fast Mapping and Explicit Encoding in Adults

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Abstract

Introduction: Animacy effects refer to the processing advantage of animate concepts over inanimate concepts, and this effect has been studied using episodic memory tasks. However, animacy effects in the context of novel word learning, specifically through fast mapping (FM) and explicit encoding (EE), remain under-researched. Furthermore, the role of overnight consolidation of animate and inanimate novel words encoded through FM and EE remains unknown. Hence, the current study was undertaken to explore animacy effects in novel word learning through FM and EE and its modulation following overnight consolidation. **Methods:** Sixty-four healthy adults learned 24 novel words through standard FM and EE tasks and completed a delayed recognition test on the day of encoding and on the following day. **Results:** Results revealed a reliable animacy effect on both days in the recognition rates, with FM encoded-words reaching statistical significance. Of the encoding methods, EE was found to be superior than FM for novel word learning, but overnight consolidation leads to the decline of words encoded via EE alone. Overnight forgetting affected animate and inanimate words equally. **Conclusion:** The findings suggest the role of animacy in novel word learning tasks based on FM and EE. However, the data-driven cues recommend that future studies should focus on forgetting rates of animate and inanimate words as the encoding advantage noted for animate words did not influence forgetting rates following overnight consolidation.

Keywords: Animacy, declarative memory, forgetting, overnight consolidation, recognition

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Introduction

Animate words are better processed in memory than inanimate words.[1,2] This advantage of animate over inanimate words has been well recorded in various memory measures such as free recall,[3,4] cued recall,[5,6] recognition memory,[3,6] and paired associate learning tasks.[6] The adaptive-functionalist view of memory[7,8] suggests that animacy advantages are seen because of an evolutionary bias. Since animate nature satisfies the role of both prey and predator, the animate knowledge was noted critical for survival on evolutionary lines. However, the scope of animacy advantage in the context of novel word learning through fast mapping (FM) and explicit encoding (EE) has not been well researched. FM and EE utilize declarative memory, and their roles in novel word acquisition have been studied.[9] FM has been widely reported in child language acquisition literature.[10] However, its interest in adult word learning has only grown recently after the remarkable finding by Sharon *et al*.[11] who showed that hippocampal amnesics, who failed to learn novel words via EE, demonstrated successful novel word learning through FM. Unlike direct encoding, FM employs encoding in the background of established knowledge utilizing a yes/no question based on the novel concept to be learned [Figure 1].[11]

Past studies in healthy controls have shown EE to be superior than FM for encoding novel words.[11,12] For declarative learning through EE, initial encoding takes place in the hippocampus, and then, there is a slow consolidation of novel information to semantic long-term memory in neocortical areas of the temporal lobe.[13] FM is reported as an alternative

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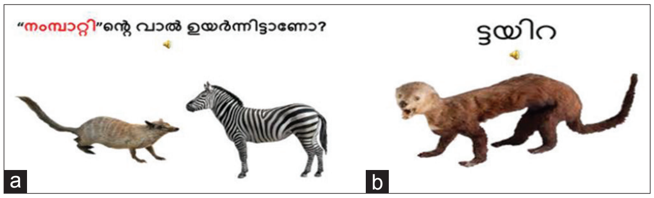

Figure 1: Represents an example of the fast mapping (a) and explicit encoding (b) paradigms used for encoding novel words. In (a), the yes/no question provided in Malayalam written and audio format is, “Is the numbat’s tail pointed up?” and in (b) the written and audio Malayalam input was the word “tayra”

method for learning novel object name pairs in adults with explicit learning difficulties.[11] In addition, FM was noted to bypass the hippocampal phase of consolidation and directly translate the information to anterior temporal lobe (ATL) structures.[11,14] This finding resulted in identifying an alternative route of declarative learning that could bypass hippocampal sleep-based consolidation. FM was also shown to facilitate rapid cortical integration as it could overcome the consolidation phase.[9]

Word learning is a continuous process that extends throughout lifespan; it would be interesting to examine animacy effects in the two possible alternate routes of learning. The current study thus aimed at investigating animacy effects in FM- and EE-based novel word learning along with addressing the animacy advantages in memory following overnight consolidation. Overnight integration was considered as FM was purported to overcome the sleep-based consolidation phase. The specific objectives considered were as follows: (1) to study animacy effect in FM and EE based novel word learning and (2) to evaluate animacy effect in FM- and EE-based novel word learning following overnight integration. As per the previous literature on animacy advantages in various memory tasks, it was hypothesized that animacy effects in novel word learning would be elucidated on both FM and EE methods of encoding and would be robust following overnight consolidation too.

Methods

Participants

A total of 64 healthy adults (24 males and 40 females) in the age range of 18–45 years were included for the study. The participants were recruited by word-of-mouth from residential colonies in Trivandrum. All were right-handed individuals with Malayalam (a South Indian language, spoken in the state of Kerala, India) as the first language with normal visual and auditory skills. Right handedness was measured using the Edinburgh handedness inventory (EHI).[15] None had any known history of psychiatric or neurologic comorbidity or learning disabilities. All had to perform within the normative range in the Malayalam version of Addenbrooke’s cognitive examination (ACE – Malayalam)[16] to be included as a participant. The mean age of the participants was 25.91 with a standard deviation of 6.66 years (range = 18–45), and education was 14.56 with standard deviation of 1.78 years (Range = 12–18). The mean EHI score, along with the standard deviation, was 96.34 ± 8.12. The mean and standard deviation of ACE Malayalam total was 94.59 ± 3.12.

Participants provided their written consent before participating in the study. The study received ethical clearance from Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum.

Stimulus

All participants were given a list of 30 novel words. These 30 words were finalized as part of the first author’s doctoral research work. The novel words used in the EE and FM conditions are given in Appendix 1. For the specific purpose of stimulus development, 100 novel words with equal distribution of animate and inanimate words were rated for its familiarity on a five-point scale by ten highly educated adults with a minimum of 18 years of education. The participants were asked to rate the words on a 5-point rating scale with 0 as “not at all familiar” and 4 as “extremely familiar.” Out of the words that were rated as “not at all familiar,” 30 words were randomly selected for the stimuli set.

To verify that the novel words were unfamiliar to the participants, a prefamiliarity check was done, wherein the participants were asked to rate the words on a five-point rating scale with 0 as not at all familiar and 4 as extremely familiar. All participants rated the words as 0, meaning not at all familiar. The corresponding images for the novel words were selected from the World Wide Web under the fair use policy. Of the 30 novel words, half denoted animate category and other half denoted inanimate category.

Procedures

The experiment to tackle the novel word learning skills was carried out in a span of 2 days to understand the maintenance of learned associative pairings to the following day after overnight consolidation. Of the total 30, six words were used in practice trials before FM and EE encoding. Out of the rest 24 words, 12 words were randomly assigned to FM and EE. Out of the 12 words in FM and EE, six belonged to the animate category and six to inanimate category. The procedure followed for FM and EE was similar to a previous study[11] except for the presentation duration parameters. The presentation duration was increased to account for the learning constraints imposed by having a greater number of stimuli in the present study. In the FM condition, participants were told that they would be presented (both written and auditory mode) with two images along with a yes/no question on the computer screen. Yes/no questions were presented in Malayalam. They were told to respond to the question with a yes/no answer. Each trial was presented for 15 s within which they had to provide an answer. As soon as the response was made or after a gap of 15 s, whichever was earlier, the trial proceeded to the next stimulus set. Fifteen seconds duration was arbitrarily chosen as adequate exposure time for inferential learning. A practice phase with three trials were carried out before the actual test was initiated. The responses were noted down by the investigator. The 12 targets of FM were presented twice with two different pairings, one with a within category exemplar and other with a foil from a different category. The participants were told in advance that this is a test to understand the perceptual clarity of images presented, so that any effort for conscious learning may not happen. The stimuli were presented via HP laptop with Intel i3 core processor, and auditory stimuli were presented using the inbuilt speakers. Microsoft PowerPoint (version 16) application (Microsoft corporation, Washington, United States of America) with custom animation for the time-based display of stimuli was used. No feedback on the accuracy of yes/no questions were provided during learning conditions. All the participants could successfully infer the novel stimulus and associated words during the FM study conditions.

After a gap of 30 min, the participants were given a multiple (three alternatives) forced-choice recognition task. Delayed recognition task was conceived after 30 min in concordance with the usual time set for verbal learning tests.[17] In this task, one was the target, one was exemplar from the same superordinate category classification and the other one from an entirely different category classification (i.e., if the target is animate, one foil will be from the same category classification which was another novel target and other foil from the inanimate category and vice versa). Category classification was into animate and inanimate concepts. Thus, each novel image associated with the novel word was presented thrice, once as a target and twice as lures. Participants were presented with three response alternatives in three locations along with the numbers, i. e., (1) top-left, (2) top-right, and (3) and bottom-center of the screen with the target word written in the center of the screen. The position of the target was counterbalanced across the three response locations of the display. The participants had to tell the number of the position in which the target appears. The items were displayed up to 15 s. The participant responses were noted down in the recognition form by the investigator.

FM was followed by the EE procedure. Both conditions were done in separate sittings on the same day. In the EE condition, the instruction given at the beginning of the task was to remember the words. The study condition started with the novel word in Malayalam script being written above the image with the corresponding audio input in Malayalam. The participants were asked to remember the novel word and the image. Displays were presented for up to 15 s. After 15 s, the next stimulus appeared on the screen. The remaining 12 novel words (different from those used in FM), 6 from animate, and 6 from inanimate category were presented as targets in EE condition. After a gap of 30 min since the presentation of all the 12 targets, participants were given the three alternatives forced-choice (3AFC) recognition task similar to the FM condition. The recognition task, response measurement, etc., were similar to FM condition. The mean time difference between FM and EE study encoding conditions in participants was 1.327 ± 0.377 h. FM preceded EE in the study phase for all participants. This was to avoid participants from getting informed regarding the aspect of "purposive learning" that could affect FM task if it followed EE task, and hence, counterbalancing was not considered. The same 3AFC recognition tasks of FM and EE were repeated the next day following sleep to understand the overnight consolidation effects. Participants were not given any feedback on their performance on the 1st day. Testing occurred during day time on both days (between 9 am and 3 pm) and within participants, the time of testing was kept constant (approximately 24–26 h between day 1 and day 2). Figure 1 illustrates the FM and EE paradigms used for learning novel words and Figure 2 represents the 3AFC recognition task used in the study.

Results

They correctly recognized word scores of 64 adults for a total of 12 animate and 12 inanimate words learned through FM and EE on the day of training and the following day formed the dependent variables. Data were analyzed using the Statistical Package for the Social Sciences software version 17 (IBM, New York, United States of America). Before subjecting data for statistics, Shapiro–Wilk's test of normality was conducted to check the normality of distribution of the data. The test revealed that the collected data did not follow normal distribution for the parameters studied ($P < 0.05$). Hence, nonparametric tests were administered for inferential statistical analyses. A P value of <0.05 was considered significant. Table 1 provides the descriptive statistics for animate and inanimate words encoded through FM and EE for day 1 and day 2.

Animacy dimension on fast mapping and explicit encoding performance

Wilcoxon sign rank test, to understand the animacy effect, revealed a significant difference between animate and inanimate words learned via FM for both days. However, words learned via EE did not reach statistical significance even when the difference between animate and inanimate words were in the same direction as that of FM. Table 2 provides the results of the Wilcoxon sign rank test for animate and inanimate comparisons for FM- and EE-based novel words for both days.

Overnight consolidation on animacy dimension in fast mapping and explicit encoding performance

It was noted that neither animate nor inanimate words learned through FM showed any significant decline following overnight consolidation. On the other hand, there was a significant decline for both animate and inanimate words learned via

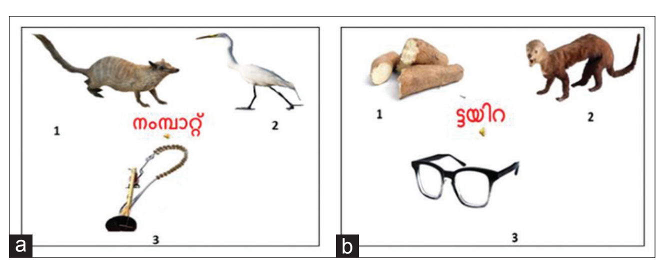

Figure 2: Represents the three alternative forced choice (3AFC) recognition task for (a) "Numbat" in fast mapping (a) and (b) "Tayra" in explicit encoding in Malayalam written and audio formats

Table 1: Descriptive statistics of fast mapping and explicit encoding encoded animate and inanimate words for both days

	FM				EE			
	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Animate words (day 1)	4.61	1	5	1	5.64	0.63	6	1
Inanimate words (day 1)	3.95	1.28	4	2	5.50	0.76	6	1
Animate words (day 2)	4.5	0.98	5	1	5.31	0.73	5	1
Inanimate words (day 2)	3.92	1.25	4	2	5.25	0.87	5	1

FM: Fast mapping, EE: Explicit encoding, SD: Standard deviation, IQR: Interquartile range

EE after overnight consolidation. Overnight forgetting was significant for EE encoded-words than FM encoded words and this forgetting was similar across animate and inanimate words. Table 3 provides the results of the Wilcoxon sign rank test for animate and inanimate words encoded through FM and EE following overnight consolidation.

Table 2: Within group comparisons of fast mapping and explicit encoding encoded animate and inanimate words for both days

	FM		EE	
	$\|Z\|$	*P*	$\|Z\|$	*P*
Animate versus inanimate words (day 1)	3.54	<0.001*	1.31	0.19
Animate versus inanimate words (day 2)	2.91	0.004*	0.43	0.67

FM: Fast mapping, EE: Explicit encoding. *: <0.05

Table 3: Within group comparisons of fast mapping and explicit encoding encoded animate and inanimate words following overnight consolidation

	FM		EE	
	$\|Z\|$	*P*	$\|Z\|$	*P*
Day 1 - day 2 animate words	1.49	0.14	3.87	<0.001*
Day 1 - day 2 inanimate words	0.47	0.64	3.26	0.001*

FM: Fast mapping, EE: Explicit encoding. *: <0.05

Discussion

This study was aimed at understanding the effects of animacy on novel word learning skills. Novel word learning was carried out using FM and EE techniques. Animacy effect was measured for both methods of novel word training. In addition to the above, another question of interest in the study was to understand the possibility of animacy advantage on novel words after overnight consolidation, for which the recognition of the novel words was tested for consecutive days.

Our results clearly demonstrated a privilege for the method of encoding than the animate category membership in the recognition memory tasks. Novel words encoded via EE were superior to FM in declarative memory functions, which was in concordance with the earlier research in normals.[9,11,12,18-20] EE technique better-aided word learning than FM in healthy controls, and this advantage was noted even on the 2nd day. A similar finding was also noted in persons with uncompromised hippocampal functions, wherein EE was reported as an effective technique for word learning.[20]

However, in both FM and EE, animate favored processing was evident. The results successfully demonstrated an advantage of animate words over inanimate words when encoded through FM, which persisted even after overnight consolidation. Better recall of animate words than inanimate words in an incidental encoding task, wherein participants had to categorize the list of words into animate and inanimate and later do a free recall task was demonstrated previously.[3] However, this substantial animacy advantage for animate words could not be elicited for words learned through EE when analyzed statistically.

Thus, in the current study, when animacy advantage was noted for words learned implicitly via FM, not finding this advantage for words learned in explicit ways was surprising. One possible reason for not eliciting a statistically significant animacy effect in recognition scores may be attributed to the nature of the task at hand, i.e., novel "word" learning itself. Novel word learning through EE required participants to establish an associative connection between novel words and related pictures within the particular time frame of exposure. There was a more conscious engagement of purposeful learning needed for EE tasks rather than a more basic subconscious allocation of attentional processes for inferential learning in a task characterized as FM. In this case, novel "word" as such would have attracted more attentional resources, and the direction of association may have happened from novel words to pictures rather than from pictures to novel words, i.e., novel word processing would have driven the association rather than pictures driving the association. Novel words *per se* had no known animacy cues.

The constrained nature of the 3AFC recognition task employed in the current study can also be postulated to be a possible reason for not finding statistical significance favoring animacy advantage in the recognition scores of words learned through EE. In the 3AFC recognition, the foils included animate and inanimate pictures along with the target picture to which the novel word had to be associated with. If the target was an animate novel word, the foil would include another animate picture and an inanimate picture (which the participant was already exposed to as target stimuli). Thus, in this paradigm, the participants could not show up the animacy advantage in recognition, possibly due to the constraints induced by the recognition task as such. In the FM task also, this same recognition task was carried out. The discernable animacy advantage noted even after following the same 3AFC recognition task in FM maybe because of the additional in-depth processing of sensory featural analysis of the pictures employed through yes/no questions characterizing the FM study paradigm. Animates have more sensory experiences when compared to inanimates,[21] and the peculiar incidental learning employed via FM could employ these sensory-perceptual advantages of processing. However, the lack of statistical significance cannot be definitively ascertained as an absence of animacy effect in EE, and rather it would have been a task-based challenge that could have masked this semantic effect from reaching statistical significance even when mean values of recognition accuracy favors an animacy advantage.

Another objective of this study was to look at how the novel words learned via both techniques undergo changes as a function of overnight consolidation. It was evident from the results that the method of encoding was superior here also than animate category membership. Overall recognition scores, though declined with the passage of time, it was noted that words that were learned through FM were more resistible to forgetting than words learned through EE following overnight integration. Korenic *et al*.[18] also reported a similar finding that the delay after learning though lead to forgetting; this was more pronounced for EE words than FM words. This differential effect could suggest the differences in the neurocognitive mediation involved in FM and EE tasks. Sharon *et al*.[11] has reported that FM employs ATL structures, while EE employs hippocampal structures. Their study was the first to suggest a nonmesial temporal lobe based declarative memory formation through FM and also stated that the new learning was durable. The current findings may also be discussed on the premise suggested by Merhav *et al*.,[9] which was based on the framework of complementary learning systems memory model. Accordingly, the better durability could be because the words encoded through FM could bypass hippocampal structures and got directly mapped to neocortical structures and could successfully bypass the consolidation (sleep) phase for encoding. Although the present results cannot definitively ascertain any of the above observations on neural substrates, it could be suggested that there is a possible differential neurocognitive involvement in FM and EE techniques of novel word learning.

Strikingly, the animacy effects on the words learned through FM and EE were retained to the following day and persisted after overnight consolidation. The animate advantage was noted on FM but not found to be statistically significant for EE on the 2nd day. There was the loss of both animate and inanimate words learned through EE following a time delay. Forgetting of words learned on day 1 was pronounced on EE without differential involvement of animate or inanimate words.

It is interesting to note that following overnight consolidation, both animate or inanimate words encoded via FM did not decay significantly. However, whatever small decline has occurred, it has happened for both animate and inanimate words. Similarly, in EE words also, overnight consolidation leads to significant decay and the decay happened for both animate and inanimate words. Animates were thought to rely on the good quality of memory traces;[3,21] however this advantage did not persist after overnight consolidation. There was no accelerated forgetting for inanimate words despite its disadvantages during the encoding phase. Forgetting equally affected both animate and inanimate words. This issue merits further research. When most studies have looked at the animacy advantages at encoding and recall levels, not finding this preferential processing at the forgetting level, is captivating. The present results did not suggest a priority for animate words during forgetting, to be specific, at least in novel word learning scenarios. However, the results are preliminary, and in view of the novelty of this finding, before any firm conclusions are made, further evidence are essential.

The findings of animacy advantage at an implicit level (incidental encoding) and higher mean scores for animate words encoded intentionally (intentional encoding) in this study, under the current theoretical understandings, does favor the adaptive memory view in lines of fitness perspective[8] or the richness of encoding[22] or greater sensory knowledge for animates compared to inanimates[23] postulations. However, the current research also put forth another major line of investigation that can potentially satisfy the opponents of the "adaptive memory view," that addressing the overnight consolidation and forgetting rates of animate and inanimate words can actually entangle the functionalist adaptation view of memory.

This study, however, is not void of certain limitations. In the study, it was established that the novel words were those which did not have pre-experimental knowledge for the participants. However, there were limitations during the selection of novel words such as not controlling the stimulus variables such as the number of letters, bigram frequency, name agreement, image agreement, and visual complexity of the pictures. However if to consider this methodological fallacy to root the animacy advantage at encoding in the current study, not finding this fallacy favoring animacy advantage at forgetting/overnight consolidation evidence against this limitation. Another disadvantage to consider was not accounting for the free recall measures, as including this could have addressed more specifically the task-based explanation on recognition scores not reaching statistical significance for explicitly encoded words.

Conclusion

This study invariably puts forth preliminary evidences of noting animacy advantage in FM and EE techniques of novel word learning. The animate advantages were more elicited in FM tasks compared to EE tasks possibly due to the former's reliance on sensory perceptual features during encoding. However, the animate preferences were not noted following overnight consolidation in either of the encoding techniques.

Hence the study endorses, forgetting rates and consolidation effects on animate and inanimate words as a potential new area to explore to elucidate further on the adaptive view of memory. This knowledge may be helpful in designing word learning paradigms for healthy subjects as well as disordered population with explicit memory deficits.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1: List of novel words used in the FM and EE conditions

	Novel words in EE condition	Novel words in FM condition
1	/ṭ̤ṭɑʝira/	/piṭ̤ṭɑ:ja/
2	/babako/	/paɑ:ka/
3	/ʧerimoʝa/	/ŋɑɱɓɑ:ʈ̤ʈɑ
4	/vaṭa: lu/	/niga:ni/
5	/go:ru/	/bogo: ḷ̤li/
6	/mekuri/	/na:spaṭi/
7	/basu:NN/	/pena/
8	/banam/	/assiga:ʝi/
9	/raba:b/	/kina:ri/
10	/kha:ru/	/sila:ʝi/
11	/ʧɑsura/	/ba:hi/
12	/kenʧi/	/ṭiliNga/

FM: Fast mapping, EE: Explicit encoding