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FAST MAPPING VS. EXPLICIT ENCODING OF NOVEL VOCABULARY: SIMILAR EFFICIENCY, DIFFERENT MECHANISMS?

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Имплицитное и эксплицитное усвоение новых слов: схожая эффективность, но разные механизмы?

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Abstract

Two language learning strategies have been described as common in both children and adults: fast mapping (FM), which promotes learning from context, and explicit encoding (EE), which is provided through direct instruction. Previous functional neuroimaging studies in adult learners have suggested differential neural mechanisms underlying these two major cognitive strategies, with some limited evidence in support of such differences also found in behavioural experiments. Nevertheless, the exact nature of these differences remains underinvestigated. Our goal was to explore putative differential effects of EE and FM strategies on

Резюме

Существуют две стратегии речевого научения, характерные как для детей, так и для взрослых: имплицитное научение (fast mapping (FM)), обеспечивающее усвоение слов из контекста, и эксплицитное научение (explicit encoding (EE)), реализуемое посредством прямой инструкции научения. Результаты предыдущих нейрофизиологических исследований демонстрируют наличие дифференциальных нейронных механизмов, лежащих в основе двух стратегий научения у взрослых; аналогичные результаты с некоторыми ограничениями показаны и при проведении поведенческих экспериментов. Однако природа этих различий остается недостаточно изученной. Цель данного исследования состояла в изучении

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the acquisition of novel words, with a focus on scrutinising the quality of recognition of newly learnt items. In two experiments, participants (total sample size = 82) learned 18 novel words presented ten times each in a word-picture association paradigm using EE and FM conditions. Learning outcomes were assessed immediately after the training using a recognition task. In both experiments, we found no differences in either the accuracy or the reaction time of word recognition between FM and EE conditions, which suggests similar behavioural efficiency of both strategies. However, we found a negative correlation between reaction time and response accuracy in recognising the words learned through EE, with no similar effects for FM, which indicates qualitative differences in underlying memory traces formed via these two acquisition modes. These results can be seen to imply that people tend to use information acquired through EE more confidently than that acquired through FM.

Keywords: word learning; memory; language acquisition; fast mapping (FM); explicit encoding (EE).

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предполагаемых различий между EE- и FM-стратегиями при усвоении новых слов с акцентом на изучении качества их узнавания. Участники двух экспериментов (общий размер выборки = 82) выучили 18 новых слов в парадигме семантического научения при предъявлении слова (по десять раз каждое) и его визуального референта в EE- и FM-условиях. Результаты усвоения оценивались сразу после обучения с помощью задачи узнавания. В обоих экспериментах не было обнаружено различий в правильности и времени реакции узнавания слов между FM- и EE-условиями, что свидетельствует об одинаковой эффективности обеих стратегий на поведенческом уровне. Однако была обнаружена отрицательная корреляция между временем реакции и правильностью при узнавании слов, выученных с помощью EE, без аналогичных эффектов для FM, что указывает на качественные различия в особенностях сохранения репрезентаций в памяти для слов, усвоенных посредством данных двух стратегий. Можно предположить, что участники исследования более уверенно использовали информацию, усвоенную с помощью эксплицитного научения, но не имплицитного.

Ключевые слова: усвоение языка, память, речевое научение, имплицитное научение, эксплицитное научение.

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Ethics Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of St Petersburg State University (protocols № 73 from 19 April 2017; № 82 of 25 April 2018).

Заявление об этике

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Author Contributions

M.F, O.S. and Y.S. designed the paradigm. E.P., M.F. and O.S. ran the study. E.P. and M.F. designed the analysis, performed the computations and prepared the first draft of the paper. D.G. supervised the findings. D.M. wrote the text in English. Y.S. and O.S. edited the manuscript. All authors discussed the results and contributed to the final manuscript.

Вклад авторов

М.Ф., О.Щ. и Ю.Ш. разработали дизайн исследования. Е.П., М.Ф. и О.Щ. провели исследование. Е.П. и М.Ф. провели анализ, выполнили расчеты и подготовили первый черновой вариант статьи. Д.Г. анализировала полученные результаты. Д.М. подготовила текст на английском языке. Ю.Ш. и О.Щ. редактировали рукопись. Все авторы принимали участие в обсуждении результатов и внесли свой вклад в окончательный вариант рукописи.

Conflict of Interest

The authors declare no conflict of interest.

Конфликт интересов

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Language is a unique human cognitive ability that differentiates people from all other living creatures on the planet. Language learning begins in childhood and continues throughout the human life. In adulthood, it occurs in conjunction with the acquisition of both native (e.g., learning new professional vocabulary) and non-native (learning a second language) lexicon. An example of the former could be the acquisition of professional concepts, which forms the basis of expert thinking. The formation and development of such a concept system depend on many factors such as the new concept's type, sensorimotor experience accompanying its acquisition, the involvement of executive functions, features of other cognitive processes taking place, learner's motivation, social interaction situations, etc. (Kostromina & Gnedykh, 2021). Last but not least, these factors include the overall cognitive strategy of acquiring a new concept, which could, for instance, be learned implicitly from the context or through an explicit demonstration/description. Identification of the cognitive mechanisms underlying a particular learning strategy may lead to new techniques for enhancing the efficiency of native vocabulary acquisition, training in professional terminology or amelioration of learning deficits.

There are two functionally distinct strategies described in language acquisition research (Bandura & Walters, 1977) through which word acquisition can occur (Dollaghan, 1985; Shtyrov, 2012; James et al., 2019; Shtyrov et al., 2019): the so-called *explicit encoding (EE)*, which is based on explicit instruction, and *fast mapping (FM)* that requires inference or deduction based on the context in which new items are encountered. EE typically involves overt explicit instruction, such as direct labelling of a new object, its comprehensive definition and/or a description of its characteristics (e.g., *this device for graphical display of varying electrical voltage is called 'oscilloscope')*; this strategy is, for instance, associated with repetitive presentations occurring during classroom lessons. FM, in turn, implies learning from context: a person is supposed to reach a conclusion about an object the new word is referring to, often based on the description of the object's characteristics and the exclusion of other candidates (*can you take the oscilloscope from the shelf ... no, not the tablet, the oscilloscope, please ... yes, the one with a little screen and a black swich)*. The latter is the most typical way through which the native vocabulary is acquired in childhood (Carey & Bartlett, 1978). In language experiments, the FM strategy is often implemented as an incidental association of a novel name with the previously unknown object presented simultaneously with a known object and a question or request related to one of these items.

In everyday life, these two strategies co-exist and partially overlap, each of them being activated depending on the exact context and conditions of learning. So far, experimental studies have yielded inconsistent results as to which of the strategies, EE or FM, is more effective in terms of new word acquisition. For instance, Coutanche and Thompson-Schill (2014) demonstrated an immediate integration of FM-learned words into the lexicon, which was not the case for EE items. On the other hand, some studies revealed significantly higher accuracy of correct matches in the semantic word-picture matching task for the EE strategy over FM (Greve et al., 2014; Cooper et al., 2019). Other studies showed no significant differences between the efficiency of two learning strategies (Warren et al., 2016; Himmer et al., 2017). Our own previous results (Shtyrov et al., 2021; Perikova et al., 2022) demonstrated very similar levels of performance for both strategies in a free recall task implemented immediately after a word learning session.

Studies of FM efficiency in patients also showed diverse results ranging from successful FM (but not EE) learning performance in hippocampally damaged individuals (Sharon et al., 2011) to the absence of any effect whatsoever (Warren & Duff, 2014; Warren et al., 2016; Smith et al., 2014). Some researchers go as far as questioning the very existence of FM in adults (Greve et al., 2014; O'Connor et al., 2019; Cooper et al., 2019).

In sum, while some available results do indicate the existence of differential mechanisms underlying these two learning strategies, these differences remain evasive and to a degree controversial. What could be the reason for that? Possibly, a direct comparison of learning efficiency between the two strategies is not the most sensitive approach to detecting such differences, as the same behavioural performance could be achieved via different routes, and therefore other levels of investigations may be required. Indeed, differences between the two strategies could be found at the neurophysiological level. For instance, a recent electroencephalography study found the acquisition of novel word forms to be equally successful in both conditions, whilst the patterns of ERPs elicited by items learned in EE and FM conditions differed in their scalp topography and temporal dynamics (Shtyrov et al., 2021).

Such more "implicit" measures could help finding the differences in behavioural outcomes as well. For instance, previous studies that considered confidence ratings, errors, and correct recognition rates, have shown that picture-word associations acquired through FM might be weak (Smith et al., 2014), frail (Munro et al., 2012), and susceptible to interference starting on the next day after the initial learning (Merhav et al., 2014). As suggested by some researchers, the first association between word form and object formed through FM may first be encoded as a hypothesis (Medina et al., 2011; Trueswell et al., 2013). Later, when the individual encounters the same word again, the initial hypothesis regarding its meaning is recalled and tested in a new context. If this hypothesis is not confirmed, it could be either rejected or altered. Presumably, the initial associations between word forms and objects acquired through FM stay frail until they are verified, in order to avoid solidifying errors concerning the new words.

According to Merhav and colleagues (2014), susceptibility to interference could be an FM-specific neural mechanism that allows storing accurate representations over a long period of time and erasing incorrect associations in the face of conflicting evidence. These authors added an interference between the novel word forms (that were to be learnt either through FM or EE) into their word-picture association paradigm: a label that was associated with one picture at the first stage of learning procedure was associated with another picture at the second stage. The results showed contrasting patterns of sensitivity to interference for FM and EE learning strategies. In the FM condition, learning outcomes did not differ between the non-interference group and the group that received interference after a 5-minute delay. However, interference after a 22-hour delay significantly decreased correct recognition rates compared to the non-interfered condition. In contrast, in the EE conditions there was no evidence of interference delay effects on learning outcomes.

As Cooper, Greve and Henson (2019) pointed out, differences between FM and EE could be found through assessing learning outcomes with implicit measures (such as reaction time), rather than more direct accuracy assessments. The study of Coutanche and Thompson-Schill (2014) used a lexical competition measure based on delays in responses to phonologically similar words (lexical neighbours) to evaluate the integration of novel words into lexicon (the task first used by Bowers and colleagues, 2005). Their study showed that cognitive mechanism of EE is characterised by the gradual consolidation of associations that is typical for declarative memory. Participants did not demonstrate evidence of lexical integration soon after training in EE mode: their response time was similar for words with and without lexical neighbours for the newly learned words. In contrast, learning through FM led to an almost immediate (ten minutes after learning) lexical competition, which could be still registered on the next day. These results clearly suggest differences in the mechanisms of information encoding for the two learning strategies.

As mentioned, some authors state that specificity of FM lies in forming "hypotheses" that remain to be verified later (Merhav et al., 2014). If the new input contradicts such hypotheses, this leads to a "reset" of the system and associations' destruction (Medina et al., 2011; Trueswell et al., 2013; Atir-Sharon et al., 2015). However, experimental results confirming the existence of such a mechanism remain scarce, and the evidence of a "hypothetical" nature of novel FM representation still has to be found. According to Cooper, Greve & Henson's (2019) suggestion above, we hypothesised that differences between FM and EE could be identified using more sensitive implicit measures for assessing learning outcomes such as reaction time.

In order to fill this gap and scrutinise potential differences between the mechanisms employed by these two strategies, we ran two experiments aimed at maximal balancing of EE and FM conditions, in which healthy adult participants learnt new words through an association between auditory word forms and visual images. Our goal was to investigate putatively different effects EE and FM strategies may have on acquisition of novel words that were quantified using accuracy and reaction time in a recognition task immediately after the learning session. Importantly, not only did we examine these two variables directly, but, in order to further evaluate the learning mechanisms, we also investigated correlations between accuracy and reaction time in the two conditions. A body of results has shown that correct answers are typically given faster than the wrong ones, which can be viewed as an indicator of individuals' confidence in accuracy of their answers and their ability to assess the possibility of giving an erroneous answer (Allakhverdov, 2000). Such an implicit indicator of the subject's confidence in their responses may in turn testify to what degree the novel associations remain in their "hypothetical" form and thus test the above suggestion regarding FM's unique distinction from the EE strategy.

Method

Learning procedure

Two experiments were carried out using a novel protocol for learning novel word forms (labels) with picture associations in FM and EE conditions (for details, see Shtyrov et al., 2021, 2022; Perikova et al., 2022). Participants were asked to answer (using button presses) auditorily presented questions about the characteristics of the objects they were unfamiliar with, such as obsolete musical instruments or rare insects. The labels of the objects were novel word forms created by recombining onsets and offsets of real Russian nouns to produce novel meaningless word-like items. These verbal stimuli fully conformed to Russian phonology and phonotactics but had no pre-existing meanings in the actual language. As a result of the learning task, participants were expected to form novel associations between these objects and their labels.

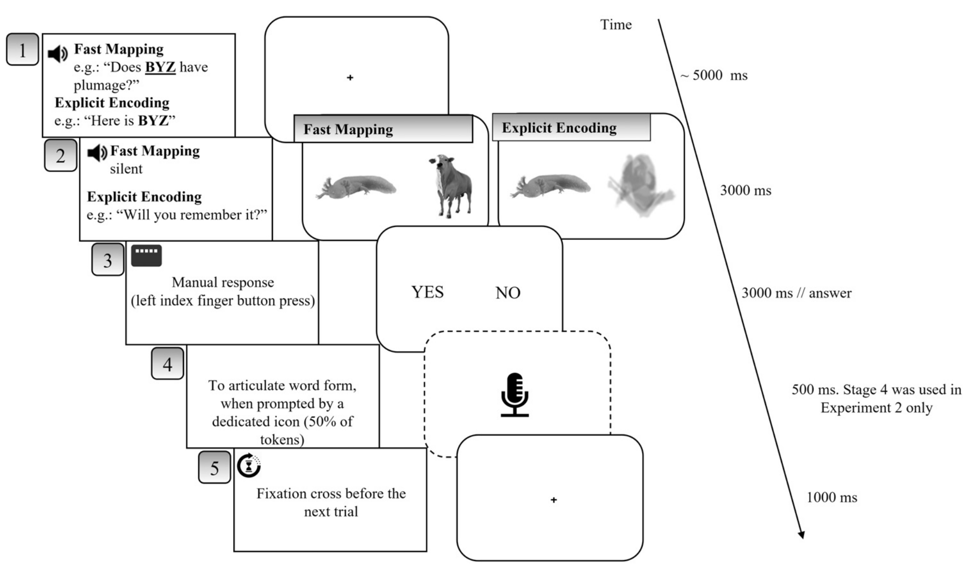
Each trial began with a fixation cross presented in the centre of the screen for 5 seconds together with an auditory word form and a question. After that two images (target and non-target ones) were displayed for 3 seconds. In the FM condition, the participants had to answer a question about visual characteristics of the target object (e.g., "Does BYZ have ears?") using contextual information from the question to exclude non-target familiar objects and thereby infer the item indirectly implied by the question. In the EE condition, the participants' goal was to explicitly associate the auditory word form with the target object. For this purpose, the target object was directly introduced through a spoken question explicitly referring to the object labelled by the word form (e.g., *"Here is BYZ – do you like it?"*). The balancing of the visual presentation mode between the two conditions was ensured by presenting the target image side-by-side with a filler stimulus (a meaningful image). The left/right position of the target picture was balanced across the learning trials for both conditions. Participants selected a *Yes/No* answer by pressing a button with their left index finger using a response pad (RB-740, Cedrus Corporation, San Pedro, CA, USA). Response time was limited to 3 seconds. As a result, each participant was suggested to learn words in both EE and FM conditions. Each word form with a unique object picture was presented ten times, each presentation being accompanied by a unique picture as a referent, to ensure generalisation of the newly acquired representations. During the experiments, the participants were seated in front of a personal computer screen in a semi-dark and acoustically shielded room.

To assess the learning outcomes, the participants were given an auditory recognition task immediately after the learning session. The participants' task was to identify whether they had encountered the stimuli earlier during the experimental session. The task aimed to test the recognition of auditory-speech patterns and did not imply semantic reproduction. After the presentation of each stimulus, participants pressed the "yes" button in case they believed that the stimulus had been shown to them earlier, and the "no" button in case it had not. The time allowed for response was 5 seconds. During the auditory presentation of the word forms a fixation cross appeared in the centre of the screen. Such tasks traditionally do not show evidence of any speed-accuracy trade-off (Stip et al., 1994; Dorry, 2010).

The two experiments differed slightly in the number of word forms presented for learning and testing. The subjects learned ten associations between word forms and pictures in the first experiment and only eight associations in the second one; in each experiment one half of the associations was learned in the EE condition, the other one in the FM condition. In addition, in the second experiment, for 50% of the target words presented in both conditions, a prompt for articulation appeared in the centre of the screen, after which the subjects had to repeat the word they heard. The smaller number of associations in Experiment 2 was related to this more complex task. More details about the stimuli and the learning procedures used in the two experiments can be found elsewhere (see Shtyrov et al., 2021, 2022, and Perikova et al., 2022, respectively). An example of a trial sequence is shown in Figure 1.

Figure 1

An example of a trial sequence in Experiments 1 and 2



Note. Experiment 1 used learning tasks without articulation, while Experiment 2 also involved articulation on novel words for 50% of items (Stage 4).

Participants

Fifty volunteers (31 females, 18–31 y.o., mean age ± SD 22.51 ± 3.53) participated in the Experiment 1. Thirty-two volunteers (20 females, 18–31 y.o., 23.37 ± 3.49) took part in the Experiment 2. The two samples did not overlap. The size of samples was determined based on previous research on learning strategies (Greve et al., 2014; Zaiser et al., 2022; Li et al., 2020), as well as similar experiments studying associations between labels and a visual reference (Zettersten & Lupyan, 2020). All participants were healthy right-handed (as established using the Edinburgh Handedness Inventory; Oldfield, 1971) native speakers of Russian with no language deficits and no prior history of any neurological or psychiatric disorders, alcoholism, or drug abuse. All of them had normal or corrected-to-normal vision.

Statistical Analysis

We carried out the statistical analysis using SPSS 26.0 software (IBM Corp., Armonk, NY, USA). To assess the efficiency of novel words acquisition we used two behavioural outcomes: response accuracy (in %, based on the number of correctly recognised items) and reaction time (RT, ms). Both parameters were calculated separately for EE and FM conditions individually for each participant. Analysis of the RTs included all responses. We used Kolmogorov-Smirnov test to check for normal distribution of the measurements in our dataset. To assess the efficiency of novel word acquisition for two learning strategies we compared behavioural outcomes for EE and FM conditions with Student's t-test (paired samples, two-tailed). Pearson's paired correlation analysis (Pearson's correlation coefficient) was used to assess connections between accuracies and RTs. Furthermore, we estimated the putative advantage of correct over incorrect responses (as an indirect measure of the individual's confidence in their responses; see Introduction) in the two conditions. To this end, we calculated differences between the RTs of correct and incorrect responses, separately for the two learning conditions. RTs were computed for each participant for words learned through both strategies and then submitted to a t-test for a statistical comparison between FM and EE conditions.

Results

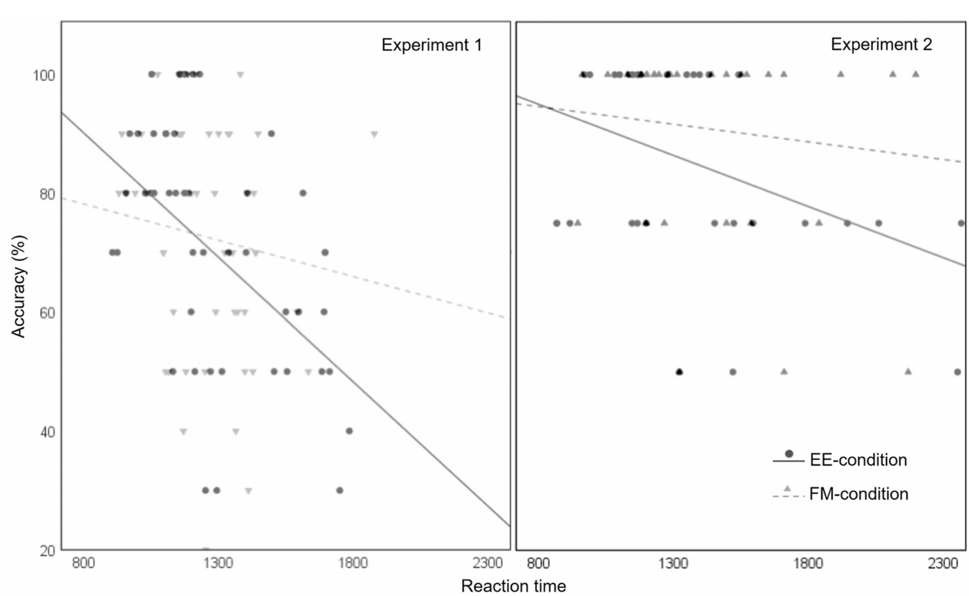
All descriptive results below are reported as mean ± standard deviation (SD).

In Experiment 1, accuracy and RTs of novel words recognition for EE (accuracy: 69.8 ± 22.8%, RT: 1285 ± 248 ms) and FM (accuracy: 72 ± 19.6%, RT: 1287 ± 249 ms) conditions did not differ significantly (accuracy: t = 1.037, p = 0.305, RT: t = 0.061, p = 0.951). The RT (RT difference between correct and incorrect responses) values were significantly greater for words learned in the EE than in the FM condition (FM: = −22.8 ± 31.8 ms, EE: = −9.9 ± 22.6 ms; t = −2.460, p = 0.017). Pearson's correlation analysis revealed a negative relationship between accuracy and RTs for EE-learned words (r = −0.457, p = 0.0009): better accuracy corresponded to faster responses (see Figure 2). No similar correlation was found for FM-learned words ($r = -0.152$, $p = 0.292$). Notably, there was no evidence of any speed-accuracy trade-off for any of the conditions.

In Experiment 2, accuracy and RTs for two learning strategies did not differ either (EE: accuracy 85.2 ± 16.6%, RT: 1373 ± 386 ms; FM: accuracy 90.6 ± 16.5%, RT: 1475 ± 374 ms; accuracy: $t = 1.561$, $p = 0.129$, RT: $t = 1.531$, $p = 0.136$). The design of this experiment allowed us to additionally assess behavioural outcomes for articulated and non-articulated novel word forms, which were learned in EE (articulated: accuracy 87.5 ± 21.9%, RT: 1355 ± 525 ms; non-articulated: accuracy 82.8 ± 24%, RT: 1390 ± 433) and FM (articulated: accuracy 92.2 ± 22.4%, RT: 1504 ± 587 ms; non-articulated: accuracy 89.1 ± 21%, RT: 1445 ± 441 ms) conditions. None of the direct comparisons between conditions elicited significant results (articulated – accuracy: $t = 1.000$, $p = 0.325$, RT: $t = 1.490$, $p = 0.146$; non-articulated – accuracy: $t = 1.000$, $p = 0.325$, RT: $t = 1.624$, $p = 0.537$). As in Experiment 1, the RT values (correct vs. incorrect responses) were larger for words learned in the EE than in the FM condition (FM = −26.1 ± 27.9 ms, EE = −1.2 ± 53.1 ms; t = −2.360, $p = 0.025$). However, similar to Experiment 1, we found a negative correlation between accuracy and RT for EE ($r = -0.400$, $p = 0.023$), but not for FM ($r = -0.135$, $p = 0.462$). Similar to Experiment 1, there was no evidence of any speed accuracy trade-off.

Figure 2

Correlation models of the relationship between accuracy (%) and RTs (ms) in the recognition task for novel words learned through EE and FM conditions in Experiments 1 and 2. Dots correspond to average accuracies and RTs of individual participants



Discussion

To investigate potential differences in the quality of novel word learning through the two major word acquisition strategies, fast mapping and explicit encoding, we balanced these two conditions for various parameters and exposed our subjects to novel vocabulary in a short audio-visual association session, the outcomes of which were evaluated using an auditory word recognition task. Two experiments, using different samples of participants, were run: Experiment 1 used learning tasks with no articulation, whereas Experiment 2 introduced an additional manipulation of asking the volunteers to articulate 50% of the items. Direct comparisons of reaction times and accuracies between the two conditions did not produce any significant results. Furthermore, learning outcomes in both cases showed success rates with above-chance performance. However, the results of the correlational analysis of behavioural data collected in both experiments revealed a negative correlation between reaction time and accuracy of the answers given in the word recognition task for words learned through EE. This correlation showed that participants gave correct responses faster than the wrong ones. However, such correlation for words learned through FM was numerically lower. Furthermore, direct comparisons of the differences between RTs for correct and incorrect responses showed that this difference (△RT) was significantly larger for EE words than for FM ones in both experiments. One possible explanation for this pattern is that participants had different levels of confidence in the correctness of their recognition of word forms learned through different learning strategies. A similar trend is known to manifest itself in different tasks, where participants are focused on accuracy (rather than speed) of the decisions they make (Harrington & Carey, 2009; Pellicer-Sánchez & Schmitt, 2012). Such a correlation could indicate that participants had greater confidence in the correctness of their answers (Allakhverdov, 2000, 2021).

In the present experiments, participants were required to respond as quickly and accurately as possible. A similar effect was previously observed in the Yes/No Vocabulary Test (a linguistic task similar to the lexical decision task), in which the participants were asked to recognise familiar words: correct answers were given faster than incorrect ones (Harrington & Carey, 2009; Pellicer-Sánchez & Schmitt, 2012). Moreover, Harrington and Carey (2009) noted that such a correlation between accuracy and speed is more typical for advanced learners than for beginners. The more experience in using a language a person has, the more confident (s)he is in using the lexicon of this language. Due to the new words created on the basis of existing Russian words in our experiments, we could expect a good acquisition of such materials by Russian-speaking respondents. And new words acquisition rate was more than 70%. Indeed, we revealed the correlation between reaction time and accuracy for the words studied in the EE condition, which allows us to equate our participants to advanced learners. Hui and Godfroid (2021) found similar effects using a different type of analysis in their recent study with Chinese students studying in the USA. The participants took a listening comprehension test and an auditory Yes/No lexical test to determine their knowledge of a word meaning in their second language. Regression analysis showed that the accuracy and reaction times of responses in the lexical test were significant predictors of a successful result in the comprehension test. Crucially, whereas the contribution of the accuracy showed a positive coefficient, the RT's contribution had a negative one. In other words, more successful comprehension was linked to higher accuracy and to lower RT in the lexical test. In sum, the phenomenon of a relationship between response speed and accuracy manifests in various linguistic tasks. The important novel finding of the present study is that we registered such a relationship for newly acquired words. Furthermore, our results show that this is true only for explicitly learned words, with no similar relationship for the items learnt via the implicit fast-mapping route.

The absence of significant correlation in the FM condition may indicate that participants showed low confidence when recognising correctly FM-learned words. It may also suggest that participants are able to assess the likelihood of their response being wrong after EE, but not after FM. However, since we did not find any differences in success levels of recognising words learned through EE and FM (measured through accuracy), we may assume that this hypothetic lower confidence in case of FM-learned words does not affect the overall efficiency of this strategy. Thus, although the mechanisms underlying representations formed via these different routes may be different, they still lead to similar overt performance. Further experiments are needed to verify this suggestion, most importantly by testing the present effects (found immediately after learning) at longer delays, such as after an overnight sleep or even longer intervals (days/weeks).

The findings are consistent with the results of the study by Merhav, Karni and Gilboa (2014), which assessed response confidence in a semantic learning task. The level of confidence was higher for correct answers compared to incorrect ones in both EE and FM conditions. According to the authors, this result indicates that new associations between words and pictures are stored in a form of declarative (explicit) memories (Haist et al., 1992). However, participants in the FM group were less confident in their correct answers, both immediately (tested shortly after learning) and after a delay (the next day), as compared to the participants in the EE group. This result is consistent with the general concept of implicit learning, which may contain both conscious and unconscious elements (Cleeremans, 2001; Dienes & Scott, 2005). Dienes & Scott (2005) employed artificial grammar learning tasks to study implicit acquisition of unconscious and conscious knowledge of structure (structural knowledge). According to the authors, structural knowledge consists of different types of knowledge, such as knowledge of rules, knowledge of whole exemplars, or knowledge of fragments. Their participants made judgments about the construct of different types of knowledge and their presence in a specific task, while structural knowledge was contrasted with judgment knowledge. As a result, conscious structural knowledge leads to conscious judgment knowledge. However, if structural knowledge is unconscious, judgment knowledge could still be either conscious or unconscious. The latter might also refer to FM-learned words: the participants might be confident in their recognition of FM-learned words without the confidence in their meaning. Here, structural knowledge is unconscious while judgment knowledge is conscious. This latter interpretation is speculative and should be tested in future experiments.

That said, some studies produced results contradicting the above pattern. In the study by Smith and colleagues (2014), correct responses were accompanied by higher confidence ratings in both FM and EE conditions after 10 minutes and a 1-week delay in one of their experiments (each item shown two times during the learning session). In contrast, in their second experiment with the same group of participants and different stimulus setup (each item presented four times), half of the participants gave higher confidence ratings for their correct responses than for incorrect responses in both learning conditions immediately after the learning session and with a 1-week delay, whilst in the other half of participants the confidence ratings for correct and incorrect responses did not differ. However, this study was run using older-age participants, which might explain the discrepancy with the Merhav et al. results above. To clarify the role of confidence in EE and FM learning strategies, future research should control for and balance physical, linguistic, pragmatic and other parameters between the two strategies as well as take into account various intervening variables such as individual characteristics (age, language experience, etc.).

Limitations

As mentioned, we interpret the results of our study as an indication that, at least immediately after learning, one feels more confident about novel words acquired through EE learning than about the concepts whose meanings were deduced from the context (through FM learning). However, in this study, we did not directly register the subjects' confidence in their answers. Hence there might also be other factors influencing the present relationship between reaction times and responses' correctness in the word recognition task. In addition, these results were obtained through assessment of novel word acquisition performed immediately after learning. Further research is needed to investigate whether these effects persist for a longer period of time and to identify the role of overnight consolidation in this process. Finally, we only assessed perceptual recognition of auditory word forms, which to some extent limits generalization of the present effects to the actual acquisition of the novel concepts' meaning (semantics). Further research could include more semantically focused tasks (e.g., word-picture matching, semantic decision, etc.) for assessing word-object association experience in learning novel word meanings more directly.

Conclusion

The present results can be viewed in a way that participants use information acquired through EE more confidently, as if it were more reliable and "verified". In turn, FM-learned associations are likely treated with lower confidence and could be labelled as "hypothetical" until they are verified through additional encounters. These results support the notion of equally efficient, but (at least partially) distinct systems for word acquisition. Furthermore, the present finding may in future be used to inform educational practices. For instance, as the present results suggest that EE learning might enhance the students' confidence in their knowledge, this strategy may be beneficial for acquiring complex or large vocabularies, whereas FM learning can be applied to studying complex concepts in conjunction with a classroom discussion of the students' hypotheses regarding the meanings and characteristics of novel concepts. These suggestions are at this stage provisional and remain to be tested in future studies.

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