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Transfer Effect in Selective Reproduction of an Implicit Sequence

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Abstract
Introduction. This article discusses current issues of implicit knowledge usage. A brief literature review presents the data on two types of implicit learning: 1) learning a system of rules (in artificial grammar learning) and 2) understanding the alternation patterns of stimuli (in learning sequences). This review showed that there are no results of partial reproduction of an implicitly memorized sequence. The study used the transfer effect since it allows modeling various conditions for usage of implicit knowledge and reduces explicit control. This study aimed to detect the transfer effect in selective sequence reproduction. **Methods**. The study was carried out in the sequence learning paradigm. At the first stage, a perceptual sequence was presented in the experimental group. At the second stage, the stimuli were arranged in a horizontal row. Several stimuli of this spatial sequence corresponded to the architecture of the perceived sequence of the first stage. Stimuli were presented randomly in the control groups. The sample comprised 45 subjects. **Results and Discussion**. The subjects of the experimental group showed a statistically significant decrease in the reaction time to the stimuli of the spatial sequence that corresponded to the architecture of the perceived sequence. **Conclusion**. The transfer effect was presented in selective reproduction of both an implicitly learned system of rules and patterns of stimuli alternating. The findings from this study support the idea that not only fragments but also general abstract structures of sequences are implicitly memorized.

Keywords
implicit learning, sequence learning, transfer effect, selective reproduction, cognitive unconsciousness, perceived sequence, spatial sequence, artificial grammar, system of rules, pattern

Highlights
- The transfer effect is used to investigate the usage of implicit knowledge in various conditions.
- A comparison study on two types of implicit learning – learning a system of rules (in artificial grammar learning) and understanding the alternation patterns of stimuli (in learning sequences) – showed a lack of data on the transfer of sequences.

➢ The transfer effect in the selective sequence reproduction manifests itself in an increased reaction to stimuli that were presented as elements of a previously learned implicit sequence.

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Introduction

The results of research in cognitive psychology have shown that implicit learning (IL) underlies the ability to assimilate numerous patterns and systems of rules in cases where they do not need to be fully assimilated. The subject acquires and uses information without knowing about its presence or essence (Agafonov, Burmistrov, Kozlov, & Kryukova, 2018; Ivanchei, 2014; Ivanchei & Moroshkina, 2011; Kryukova, 2016; Moroshkina, Ivanchei, & Karpov, 2017; Ushakov & Valueva, 2006; Cleeremans, Allakhverdov, & Kuvaldina, 2019; Iwasaki, Kuriyama, Kondoh, & Shirayori, 2018).

Most often, learning and the subsequent use of knowledge takes place in different conditions. In the field of IL research, this phenomenon of application of knowledge is called the 'transfer effect'. A. Reber, who was among the pioneers in this field, applied an experimental technique that became the basis for further methods for studying the transfer effect.

In 1967, A. Reber proposed an experimental technique to study the phenomenology of IL. The method was called 'artificial grammar learning'. What is this kind of grammar? This is a system of rules by which the experimenter can generate so-called grammatical lines of symbols. Figure 1 demonstrates the artificial grammar used by A. Reber in the first experiments.

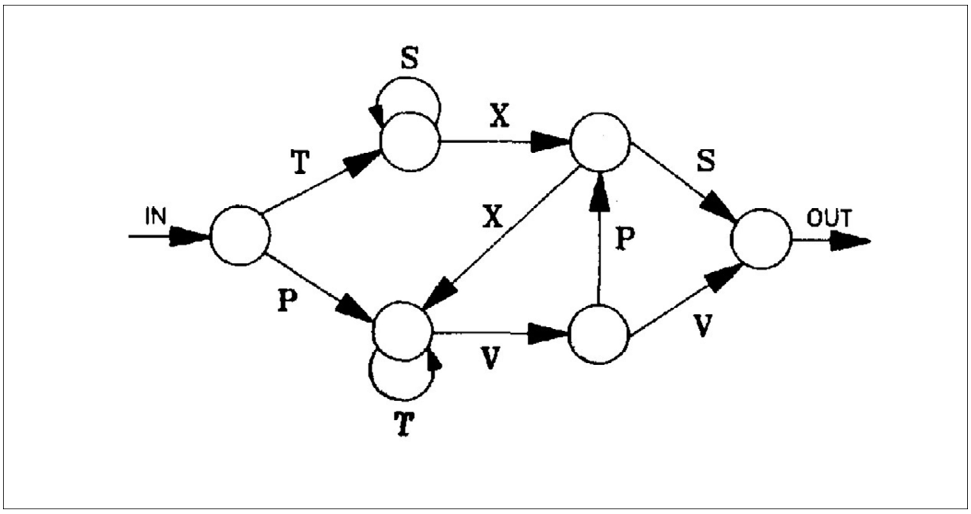

Figure 1. Artificial grammar (A. Reber, 1967)

An example of a grammar line would be TSXXTVPS. The line VTPPVSSS is agrammatic, which means that it is not constructed by the rule (Reber, 1967).

In a series of experiments, A. Reber showed that without knowing the rule for composing lines, subjects are able to quite effectively distinguish 'correct' rules from 'incorrect' ones. But this is only possible if they were trained before to perceive and memorized only grammatical lines.

A. Reber argued that the transfer effect manifests itself whenever previously learned rules are applied during the processing of new information. The very fact that the effective distinction between grammatical and agrammatical lines at the test stage is already a manifestation of the transfer of the rule implicitly learned at the training stage. But the transfer effect manifested itself in another experiment with the same artificial grammar at the training and test stages, yet different symbols used (at the test stage the alphabet changed but the grammar remained the same). In this case, although the subjects categorized lines somewhat worse, the amount of correct answers remained above the level of random guessing. In other words, under new stimulus conditions the subjects unconsciously discovered the grammar structure that was learned during the first stage (Reber, 1967; Reber, 1989; Reber, 1969).

The research direction found by A. Reber was continued by J. Altmann and colleagues. In their experiment, the subjects perceived visual stimuli (lines of letters) at the training stage. Notes were used as test stimuli instead of letters. Thus, the subjects had to perceive short melodies as stimulus sequences. The task was to differentiate the audial stimuli into those grammatical and agrammatical ones. The results showed that the subjects performed successfully, although they could not explain the rule for organizing rows of stimuli. The authors conclude that the area of transfer is not limited by the modality of perception (Altmann, Dienes, & Goode, 1995).

As further studies have shown, the transfer of implicit knowledge of previously learned patterns does not depend on the type of learning activity. Thus, in our earlier study, the standard procedure for using artificial grammar included one more new part. After training and test stages the subjects went through the control stage, which combined two types of cognitive activity (work with grammar and sensorimotor activity). The purpose of this stage was to test the possibility of transferring the results of one activity to the process of performing another. In the experimental group, the subjects were presented with a green circle after each grammatical line, and a yellow one after an agrammatical line. According to the instructions, the subjects had to respond as quickly as possible by pressing the keys that were relevant to the color of the circle. In the control group, the circles appeared randomly. It was found that the subjects of the experimental group performed sensorimotor tasks significantly faster, but at the same time they did not realize a pattern of stimulus presentation. Presumably, the subjects of this group implicitly established a connection between the line and the color of the circle, which allowed them to expect the appearance of a green circle after a grammatical line and respond faster (Kryukova, Agafonov, Burmistrov, Kozlov, & Shilov, 2018).

According to the abovementioned data, knowledge gained in the process of IL is used in the system of rules in different conditions. Another type of implicit learning is the learning of patterns in alternating of stimuli, actions, and events. This type was explored in a popular experimental paradigm of sequence learning. This method by M. Nissen and P. Bullimer involves the presentation of certain stimuli in a certain order specified by the experimenter, while the subject does not know the rules of line architecture (Burmistrov, Agafonov, Fomicheva, & Shilov, 2021; Cleeremans, Destrebecqz, & Boyer, 1998; Clegg, DiGirolamo, & Keele, 1998; Destrebecqz

& Cleeremans, 2001; Nissen & Bullemer, 1987). This experimental paradigm is related to artificial grammar. Therefore, it was expected that the transfer effect was repeatedly found in these studies. In one of the experiments, when a stimulus appeared, the subjects were required to press the keys with the index and middle fingers of their right and left hands. At the second stage, it was necessary to react only with the index finger of the right hand. The authors of the work suppose that they have established a transfer between the executive organs, since the reaction time of the subjects at both stages was the same. Meanwhile, the transfer was absent under conditions when it was necessary to indicate the location of the stimulus on the screen verbally, and then press the keys (Cohen, Ivry, & Keele, 1990; Curran & Keele, 1993). It also turned out that the subjects reacted faster if they had previously watched the experimenter perform this task. Probably, for the most effective learning of sequences, it is necessary to combine perceptual and motor learning (Bird, Osman, Saggerson, & Heyes, 2005).

Another type of the considered effect is spatial transfer. It was discovered by K. Tanaka and K. Watanabe. They trained the subjects by demonstrating sequences using a horizontal arrangement of stimuli. At the second stage, the horizontal row was replaced by a vertical or a mirror one. Participants performed the target task more efficiently if the test sequences were composed according to the original rule (Tanaka & Watanabe, 2014). In the same research direction the data demonstrated the transfer between sequences of different types. For example, implicit knowledge of the organization of a perceptual sequence was effectively used in the course of solving problems of determining the spatial localization of a stimulus (Kryukova, 2020).

We should note that in experiments with artificial grammars, subjects are implicitly taught with a system of rules, and each grammatical line at the test stage is a fragment of this grammar. At the same time, the results of experiments performed in the sequence learning paradigm were obtained with a complete reproduction of the sequence at the test stage. However, this is precisely what has been criticized by those, who suppose that during the assimilation of the sequence the subjects explicitly memorize its constituent elements (two or three stimuli following one after another) (Perruchet, 2008; Perruchet & Amorim, 1992; Perruchet & Pacton, 2006; Willingham, 1999). At the same time, a number of researchers support the idea that during the process of implicit learning, it is precisely the organization rule that is assimilated, and that is in the pattern of the stimuli sequence, not in stimuli themselves (Reber, 1989; Destrebecqz & Cleeremans, 2001). The transfer effect can serve as confirmation of this position, since changing conditions make it difficult to apply previously learned and assimilated information that reflects only a set of stimuli without understanding the general principles of their interaction.

In order to solve the problem, we used the technique of selective reproduction in our study, which makes it possible to find the learned earlier patterns in fragments of the test sequence. Thus, the study *aimed* was to establish the transfer effect in selective sequence reproduction. We tested experimentally the following hypothesis: the reaction time will decrease for structural elements that are a part of the previously learned implicit regularity.

Methods

We carried out an experiment with a sample of 45 subjects (14 men, 31 women) aged 18 to 40 years (M = 21 years). All subjects had normal vision. The sample was randomly divided into three groups: experimental group (EG) and two control groups (CG1 and CG2). Each subject was tested individually.

The basic procedure reflected one that demonstrated the transfer of the perceptive structure to a spatial structure (Kryukova, 2020). We developed a special computer program, using that one can change the time and presentation order of stimulus material, and save the answers of the subjects in the database. The experimental procedure consisted of three stages.

At the first stage, a perceptual sequence was presented to the EG, which structure consisted of 10 elements. Four emojis were used as stimuli (Figure 2). The sequence looked like this: 4-1-3-2-3-1-2-4-1-2, where 1 is an emoji with a heart, 2 is an emoji with a cake, 3 is an emoji with flowers, 4 is an emoji with a bowtie. Emojis appeared one by one in the center of the screen. The subjects performed the task following the instructions: with the index finger of the left hand they had to press the 'space' key as quickly as possible only when an emoji with a heart appeared; when any other emoji appeared, we required to press the '→' key as quickly as possible with the index finger of the right hand. The exposure time of one stimulus was 400 ms. If the subjects did not answer during this time, then the screen remained blank until the button was pressed. The time interval from pressing a key till the demonstration of the next stimulus lasted 250 ms.

Figure 2. Stimulus material, the first stage

The first stage included 12 blocks. In first 8 blocks the sequence was repeated 9 times (there were 90 trials in each block). In block 9, 90 stimuli were presented in random order. This block 9 was composed in order to check whether the sequence was learned, in this case the reaction time would increase. In blocks 9–12 emojis were again presented according to the sequence. Between the blocks there was a 30-s pause to rest. In CG1 and CG2, the conditions were the same as in the EG, but there was no regularity in the presentation of stimuli.

At the second stage, the spatial arrangement of stimuli was used in all groups. In the middle of the screen, there was a horizontal row of ten squares, numbered from left to right (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10). The squares filled green in a sequence. The subjects had to press the key with the letter B as quickly as possible if the square numbered 1, 2, 3, 4 or 5 turned green, in other cases the letter was U. The exposure conditions were the same with the first stage. The sequence repeated 30 times.

In EG and CG1, we introduced the following rules for coloring the squares:

- the rule of the variable localization of the green signal: the first, third, fourth, fifth, seventh, eighth, tenth in turn; any square could be colored, except for the second, sixth, and ninth ones;
- the rule of the deterministic localization of the green signal: only the square numbered "2" was painted second in turn, the square numbered "6" was painted sixth, and the square numbered "9" was painted ninth.

Thus, in this study, the selective reproduction of the sequence architecture is manifested in the fact that in the EG, with the same amount (10) of elements of the perceptual sequence and the spatial series, only the order (2nd, 6th, 9th elements) of the appearance of one of the stimuli (emoji with a heart) at the first stage and the order of the deterministic localization of the green signal at the second stage are equal.

The subjects were not told about the existence of any of the rules.

In CG2 there were no patterns, which allowed carrying out a more detailed analysis of the results of the second stage among the three groups.

At the end of the main procedure, a post-experimental interview was conducted to test the ability of the subjects to explicate the sequences. Since the stimulus material was tested in a previous work on the subject of unconsciousness (Kryukova, 2020), it was decided just to interview the subjects without additional tasks.

All stimulus exposure conditions, the number of blocks and tasks, interview questions were selected basing on the experience of previous studies and our pilot experiments.

Results and Discussion

First of all, we analyzed the answers to the interview questions. Some of the subjects said that they noticed some order in the sequence of emojis, but did not understand it. The EG participants noted that their reaction time increased in one of the blocks of the first stage (this was block 9, where the sequence was broken.) However, no one saw any pattern in the second stage. Thus, the analysis of the answers showed that the subjects did not understand the rules, and no one had a solution strategy at the second stage.

Further processing of the results took place in two stages. Incorrect answers were less than 1 %; the time of these answers was not taken into account.

Implicit memorization of a perceptual sequence

First, it was necessary to make sure that the subjects learned the perceptual sequence at the first stage. As shown in previous works, in EG the results of four blocks were the most informative for analysis: block 1 revealed the initial indicators of reaction time; in block 8 the effect of learning can be fully observed; block 9 is a test block; by block 12, the effect of learning was restored. In the control groups we selected the results of the same blocks. The reaction time of the first ten presentations in each block was removed in order to eliminate the period of adaptation to the conditions of the task. Mathematical processing of the results was carried out using the two-way repeated measures ANOVA, 3x4 (3(EG, CG1, CG2) x 4(four blocks)).

Analysis of variance revealed a significant interaction of factors ($F(6; 179) = 5.14$; $p < 0.01$). This suggests that the conditions in the groups had a different effect on the reaction time in each of the blocks.

According to the clarifying data of the Tukey test, in the EG, the subjects in the block 8 spent significantly less time to answer than in the block 1: $p < 0.01$. In the block 9, when the sequence was broken, the reaction time increased significantly compared to the block 8: $p = 0.016$. In the block 12, the reaction time again significantly decreased: $p < 0.01$. These results can be explained by the fact that in block 9 the change in the order of stimuli sequence prevented the subjects from the implicit usage of the previously learned sequence. Since block 10 the stimuli continued to be presented according to the rule; the subjects were able to use it again. In the control groups, in general, there was only a slight decrease in the reaction time, which is associated with

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the effect of working out. Since the difference in conditions in the groups is due to the presence of a rule in the EG, the difference in the dynamics of the results (Table 1, Figure 3) indicates that the subjects in the EG implicitly learned the perceptual sequence.

Table 1
Describing characteristics of the first stage of the experiment

Group	Block	Reaction time (ms)		95 % confidence interval	
		Mean	Standard deviation	From	To
EG	1	395	66	358	432
	8	317	66	280	354
	9	372	48	345	399
	12	259	32	242	277
CG1	1	361	56	330	392
	8	336	46	310	362
	9	321	52	292	350
	12	341	78	298	384
CG2	1	360	51	332	389
	8	337	56	321	368
	9	332	48	318	346
	12	321	53	305	352

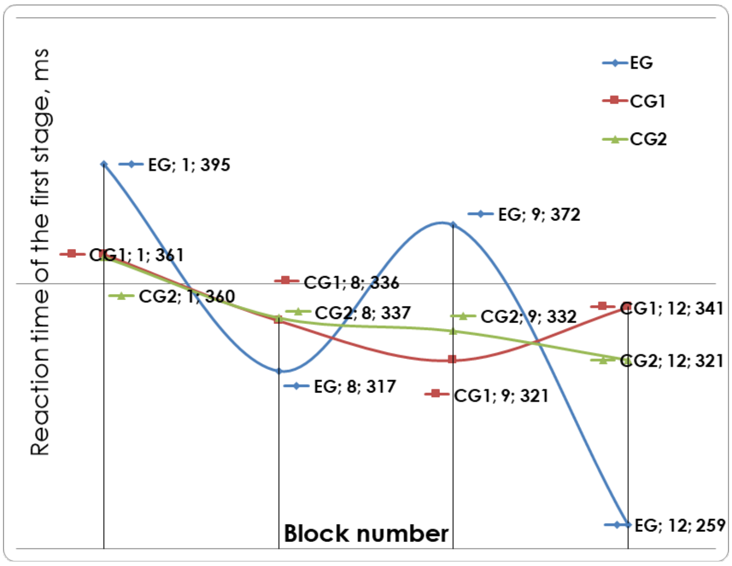

Figure 3. Results of the first stage of the experiment

Investigation of the transfer effect

The possibility of the transfer effect is determined by the results of the second stage. During the presentation of the spatial sequence, a part of the structure of sequence architecture was reproduced; the 2nd, 6th, and 9th elements were repeated. Therefore, we took into account only the response time to these stimuli. The results of the first five repetitions of the sequence were removed to avoid the influence of the adaptation period to the conditions of the task. To process the results, a one-way analysis of variance was used, which revealed a significant effect of the group ($F (2; 44) = 4.43$; $p = 0.017$). According to Tukey's test, subjects in the EG responded to the green signal significantly faster than in CG1 ($p = 0.047$) and CG2 ($p < 0.01$). The results are presented in Table 2 and Figure 4. The data indicate that it was the presence of the transfer of the previously memorized structure that contributed to the increasing efficiency of the EG. This conclusion is also supported by the fact that the presence of only a spatial sequence (which the subjects could begin to assimilate) in CG1, managed to lead to a slight increase in reaction time, compared to the indicators of CG2, where there were no patterns: $p = 0.5$.

Table 2

Describing characteristics of the second stage of the experiment

Group	Reaction time (ms)		95 % confidence interval	
	Mean	Standard deviation	From	To
EG	393	47	366	419
CG1	427	42	403	450
CG2	437	36	416	457

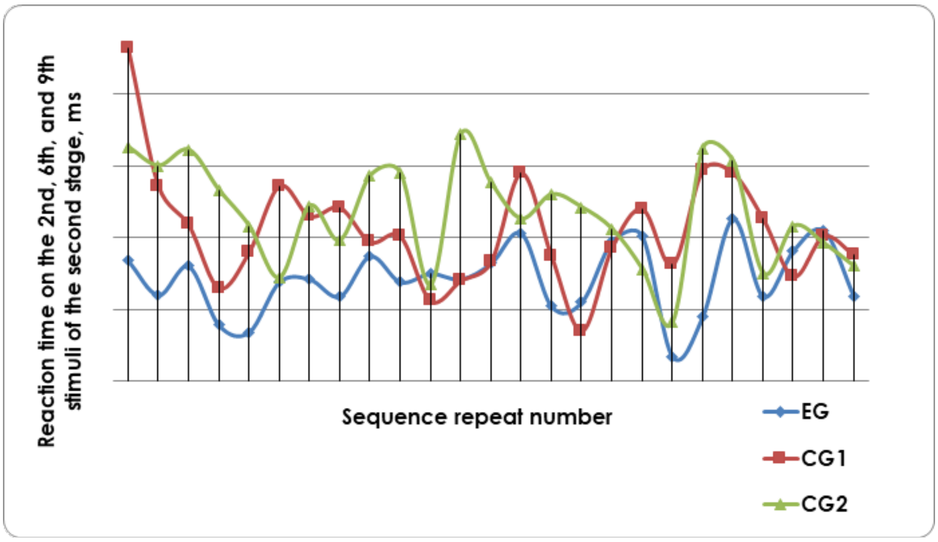

Figure 4. Results of the second stage of the experiment

Additionally, the results were compared within the EG. The response time to the 2nd, 6th, and 9th stimuli (M = 393 ms) was compared with the response time to the other stimuli (M = 407 ms). It turned out that, although the subjects responded faster to deterministic stimuli, it was not significant: $t = 1$; $p > 0.05$. Presumably, such results are due to the fact that the task of the second stage is quite simple, and it is impossible to obtain significant changes. Difficulties in obtaining fine effects have been reported before (Jiménez, Vaquero, & Lupiáñez, 2006; Sanchez, Yarnik, & Reber, 2015). Therefore, it is necessary to continue searching for optimal conditions for studying this phenomenon.

Conclusion

The study of the effect of sequence transfer was carried out using selective reproduction. It implied the repetition of several structural elements of a previously learned sequence in new conditions. At the same time, the length of the sequence (i.e., the number of elements) was the same while the stimuli were replaced. In addition, in order to make it more difficult for the subjects to use the consciously memorized sequence elements, we used the structural elements that were separated from each other.

As a result, there was an increase in the efficiency of solving the tasks where stimuli of the new sequence corresponded to the elements of the previously learned structure. Thus, the transfer effect can be observed in the selective reproduction of both an implicitly learned system of rules and the patterns of stimuli alternating.

The findings are consistent with a recent study that not only fragments but also general abstract structures of sequences are implicitly memorized (Fu, Sun, Dienes, & Fu, 2018).

The results of the study can be useful in IT companies for developing ergonomic interfaces.

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Author Contribution

A. P. Kryukova contributed to the idea and experimental design of the study, carried out statistical data processing, interpreted findings, and prepared the manuscript for publication.

A. Yu. Agafonov contributed to the idea of the study, prepared the manuscript for publication, supervised the study, interpreted findings, and provided financing.

S. B. Burmistrov conducted the experiment, selected study participants, and interpreted findings.

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