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The role of sign and its meaning in learning of categories boundaries

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Abstract

It is known that sign can help in concept formation even when it's redundant (Lupyan, Rakison & McClelland, 2007). In our research we tested the hypothesis about the impact of the word meaning in the absence of the word itself on the learning of category boundaries. Subjects were stimulated with expectations of certain meaning (priming) with the false memories paradigm (Deese, 1959; Roediger & McDermott, 1995). Then subjects were to categorize the items in the *without sign and with meaning* condition. We compared the performance in this condition with two control conditions – *without sign and without meaning* condition (first control) and *with sign and with meaning* condition (second control), when subjects were shown the image of the word naming category after receiving the feedback. The lowest reaction time scores (RT) was in the first control condition (*without sign and without meaning*) and the highest RT scores was in the second control condition (*with sign and with meaning*). RT in the priming condition (*without sign and with meaning*) was closer to *without sign and without meaning* (first control) condition. We discuss these results as the proof of a stronger impact of the sign than its meaning on concept learning.

Keywords: concept, category learning; sign; label; meaning; false memories.

L.S.Vygotsky in his book "Thought and language" in 1932 (Vygotsky, 1932/1962) wrote that concepts emerge from two bases: on the one hand, the communication, and on the other hand, from the thought. These two functions are closely connected because the words are to be related with common concepts in the mind of the speaker in the case of specific human communication. And in the case of thought verbal nature of generalizations allows us to control and create new concepts. In our study we continue the direction of research on the impact of language on the categorization It is known that language or words combine the signs and meanings (or semantics). Our point of interest is the investigation of separated impact of a sign and its meaning on categorizing an object.

On the one hand in some research it is shown that generalizations can take place in the absence of the sign (Posner & Keele, 1970). But on the other hand in many research it is shown that concept formation significantly improves if objects for categorization are accompanied by signs or words.

At present there are several directions of research considering the impact of the sign on concept formation. First of all there are studies investigating semantically empty signs. For example in the Markson and Bloom research (1997) children formed generalizations for new concepts when these concepts were marked with the artificial meaningless word (*koba*) and didn't form generalizations while they were marked with a sticker. Studies of S.Waxman (Waxman, 1990; 1995) showed how word could direct concept formation on certain (sub- or superordinate) level of generalization.

In the second direction of research the using of the sign with certain meaning is studied. For example, if we show new objects and tell different information about them (like it was animal-catching devices or pesticide-spraying devices) such diversity in naming forces subjects to pay attention on different visual parts of objects (Lin & Murphy, 1997).

So the problem is: what is more important for generalization – physical properties of a sign or its meaning? First attempt to answer this question was taken in the research of G.Lupyan and his colleagues (Lupyan, Rakison, & McClelland, 2007). In their experiment a sign involved in concept formation process was redundant, i.e. wasn't necessary for successful generalization. As it turns out, subjects in such conditions formed generalizations significantly faster compared with conditions when there were no signs. This research is very peculiar because it allows to distinguish the role of the sign from its feedback function. Thus to compare the impact of the physical sign with the impact of its meaning we were to do something similar – create such conditions where the meaning of a sign would be involved in categorization but wouldn't be connected with feedback function.

How can the sign be separated from its meaning? In other words how can the word meaning be placed into the working memory of a subject for the subject not to realize the word connected with that meaning? For that purpose we decided to use the method of false memory inducing from the memory research. False memories effect is a phenomenon arising from error-prone character of our semantic memory (Deese, 1959; Roediger & McDermott, 1995). In the absence of some relevant information our cognitive schemes complete this missing information and the subject doesn't realize what is the source of such memories (Bartlett, 1932). Inducing of the false memories in experimental conditions was first implemented in the Deese/Roediger-McDermott paradigm (Roediger & McDermott, 1995). Their participants gave almost identical confidence rating for the studied words from the remembering list and for the nonstudied but closely related associates.

Some subsequent research showed that false memories and true memories could both prime in the problem solving tasks (Howe et al., 2010; Kokinov, 1990). Thus the false memories effect is determined by the top-down processing of incoming information. So meanings of a sign have the same properties as false memories. Because of its inclusion in more common cognitive schemes or theories meanings help us to organize our perception (Murphy & Medin, 1985).

So we decided to use Deese/Roediger-McDermott paradigm (DRM) to induce the meaning of the sign without using the sign itself. We supposed that inducing false memories about the word which meaning would be related to items for categorization (for instance if we induce the word “chair” and then show objects which look like chairs) will allow us to estimate the impact of meaning on this process. For that purpose we need to compare this condition with the condition where there are no sign and meaning and the condition where there are both sign and its meaning.

Method

It was not possible to use the existing DRM-lists in our research because of the Russian-speaking sample. So first we asked a group of participants (N=21) to give us associates on 5 words such as *chair, car, tree, key* and *scissors.* Then we chose first 10 most frequent associates for each word. The other group of participants (N=25) performed test in DRM-paradigm with studied words, weakly related associates (from position 10 and below in the association lists provided by previous group) and critical lures (from which the lists were generated) in the recognition test.

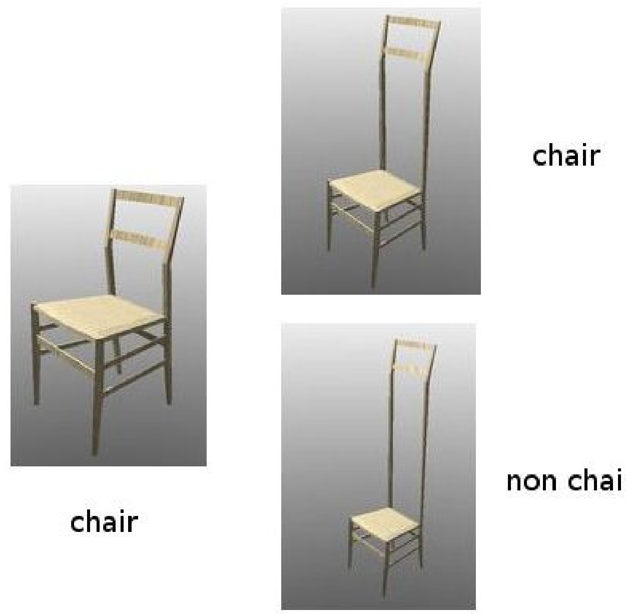
As in the DRM-test participants were asked to rate each word in the recognition part as to their confidence that it had occurred on the list (using 4-point rating scale from Roediger and McDermott study (1995)). The highest ratings of false memories were on the word “chair” (M=3,32; SD=0,85). For comparison mean rating for studied words was M=3,57; SD=0,87 and for nonstudied words M=1,34; SD=0,72.

Participants. Subjects were 56 Russian State University for the Humanities undergraduates.

Material for induction of meaning. We induced meaning of the “chair” category with the list of first 10 most frequent associates from the previous procedure (free association task). For the estimation of the induction effect we created test list of words which included four studied words (*to sit, table, wooden, back*), four nonstudied but weakly related items from the same category (*lunch, squeaky, hall, upholstery*) and the critical lure – the word *“chair”*.

Material for category formation. We created objects for categorization by modification of the four dimensions of the initial 3D model of a chair. Those dimensions were height of the back, length of the chair feet, width and length of the seat. Each dimension was enlarged on 8 values (from minimum value to exaggerated maximum one) so first four values were included in the category and last four values weren’t (Figure 1).

Figure 1: Examples of object for categorization in training phase



Thus we had 32 objects for categorization – 16 in each category. Half of them were used in the training part and half were used during the test.

Procedure. Each trial began with a fixation cross (300 ms) on the laptop display followed by an object (500 ms). After that a mask appeared (white rectangle) and remained on the screen until the response or trial timeout (3 sec). Trial’s order was randomized.

All participants were randomly assigned to one of three conditions. In all 3 conditions they were instructed that they will get the set of the images of one chair modified so that some of them didn’t look like familiar, normal chair and some of them still did. So the task was to distinguish “chairs” from “non-chairs”.

In the first control condition (*without sign and without meaning*) a participant received a feedback after his response – a bell sounded if his response was right and there was no sound for the wrong response.

In the second control condition (*with sign and with meaning*) we added the image of the word “chair” to appear in the feedback. So the word “chair” appeared on the screen (500 ms) in those trials where objects were included in the category. And there was no word image when the object didn’t belong to the “chair” category.

The third condition – experimental (*with meaning and without sign*) – was identical to the first control condition. Except that before categorization task participants got the memorization task which was suggested to induce the related meaning. Immediately after categorization task we estimate the false memories effect.

Dependent variables in all 3 conditions were performance of categorization (number of correct responses) and reaction time (RT). We used RT measure because it allowed us to estimate not only quantitative effects of learning (automation of the rule) but also qualitative (level of the rule explicitness).

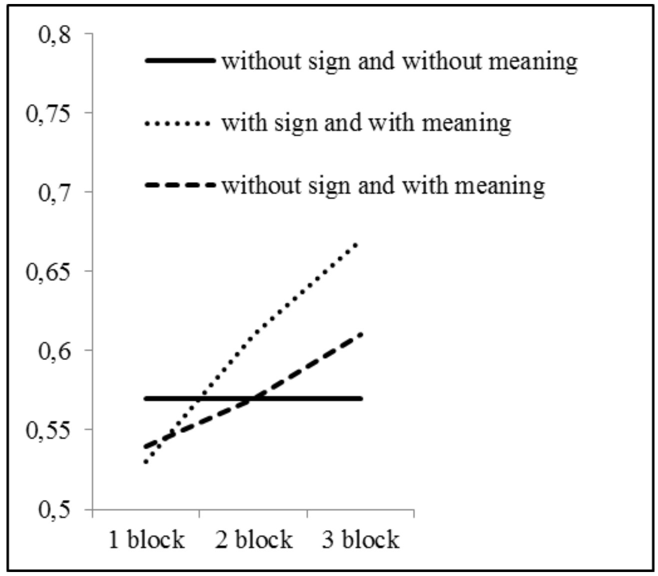
Hypotheses. We assumed that participants from the *with sign and with meaning* condition (second control condition) and the *with meaning and without sign* condition (experimental) should be more successful in their performance than participants from the *without sign and without meaning* condition (first control condition). RT scores should be higher in those conditions where sign or/and meaning included because they mediate categorization.

Results and discussion

We compared the performance on categorization task in training and test parts through all 3 conditions using repeated measures analysis of variance (ANOVA), with condition (*without sign and without meaning* vs. *with sign and with meaning* vs. *with meaning and without sign*) as a between-subjects factor and block as a within subjects factor.

There were no significant differences in performance between experimental conditions in training procedure, $F(2, 53)=.84$, $p>.1$, $\eta^2_p=.03$. However if we analyze the increase in performance in all experimental conditions separately we will found the following. In the *without sign and without meaning* condition the performance was low and it wasn't changing ($F<1$). In the *with meaning and without sign* condition the performance increased but it was significant only statistical tendency ($p=0.09$). Only in the *with sign and with meaning* condition the increase in performance was statisticaly significant ($F(2, 36)=7.13$, $p<0.01$). A summary of performance in all experimental conditions during training blocks is presented in Figure 2. Considering test procedure, we found neither significant effect of test block, $F(1, 53)=2.21$, $p>.1$, $\eta^2_p=.04$ nor significant effect of experimental condition, $F(1, 53)=1.36$, $p>.1$, $\eta^2_p=.05$. Thus our hypothesis about the lowest performance on learning of category boundaries in the *without sign and without meaning* condition (first control) wasn't confirmed. However the performance in *with sign and with meaning* condition was the highest in accordance with the part of our hypothesis.

Figure 2: Mean performance scores in all experimental groups from first training block to third and in the test.



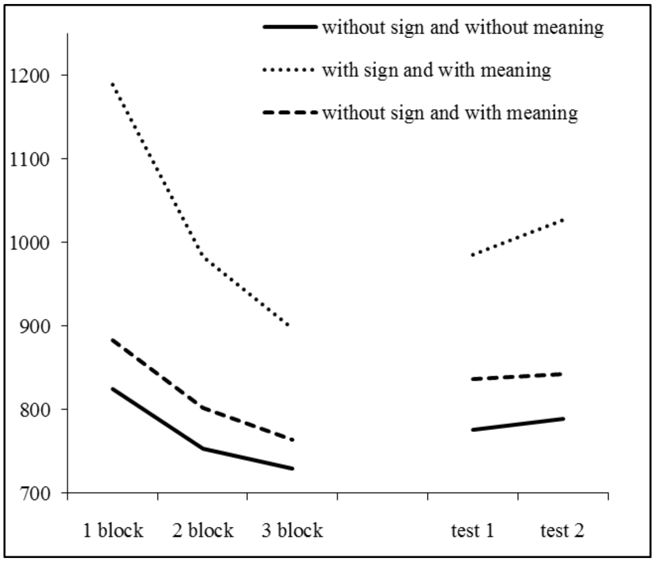
For RT estimation we took both trials with correct and incorrect responses (additionally we estimated RT only for correct responses but there weren't any significant differences).

All results were analyzed using repeated measures analysis of variance (ANOVA), with condition (*without signn and without meaning* vs. *with sign and with meaning* vs. *with meaning and without sign*) as a between-subjects factor and block as a within subjects factor.

We found significant main effects of both factors in the training procedure. So RT was significantly decreasing in all 3 groups from first training block to third, $F(2, 106)=29.35$, $p<.001$, $\eta^2_p=.36$. In other words there was an effect of training in all groups. A summary of RT in all experimental conditions for both training and test parts is presented in Figure 3.

Considering RT ratings among experimental groups we found significant differences, $F(2, 53)=5.16$, $p<.01$, $\eta^2_p=.16$. RT scores were the lowest in the *without sign and without meaning* condition during all 3 training blocks. And RT scores were the highest in the *with sign and with meaning* condition. RT scores in the third experimental condition (*with meaning and without sign*) were in between the previous two.

Figure 3: Mean RT (ms) in all experimental groups from first training block to third and in the test.



Additionally post-hoc tests (Scheffe) showed significant differences between *with sign and with meaning* and *without sign and without meaning* conditions (p<.05). Our experimental condition (*with meaning and without sign*) didn't differ significantly from *without sign and without meaning* condition (p>.1). But it differ from *with sign and with meaning* condition at the level statistical tendency (p=.054). Thus RT in category learning depended on the presence of the sign and didn't depend on the presence of the meaning – it was the sign but not its meaning that mediated categorization and participants spent some time using it.

We also found slightly significant interaction between training block and condition, F(4, 106)=3.93, p<.01, η^2_p=.13. The highest difference in RT between experimental groups was in the beginning of the training but it decreased by the end of the procedure.

Analyzing results of the test part we didn't found significant differences in RT between two test blocks, F(1, 53)=1.45, p>.05, η^2_p=.03. The main effect of experimental condition was significant but not so strong as in the training part, F(2, 53)=3.36, p<.05, η^2_p=.11. The interaction between block and condition factors wasn't significant, F(2, 53)=.43, p>.05, η^2_p=.02.

Additionally post-hoc tests (Scheffe) showed significant differences between *with sign and with meaning* and *without sign and without meaning* conditions (p<.05). But our experimental condition (*with meaning and without sign*) didn't differ significantly from *without sign and without meaning* condition (p>.1) and from *with sign and with meaning* condition (p>.1).

Thus in the test part RT increased when participants were categorizing with sign. It is interesting that unlike the training part, the group who got the induced meaning, showed intermediate RT ratings between condition where there was no sign and the related meaning and condition where there were both sign and meaning. Perhaps these results have shown the evidence of the different role of sign and its meaning in the categorization. We'll consider this assumption in details in the Conclusion.

Conclusion

Our research revealed that the sign has more impact on learning of category boundaries than its meaning. Although we found clear differences in RT in all experimental conditions during training and test blocks according our theoretical implications we didn't found same differences in performance in training and test blocks.

It doesn't seem clear enough why in the G.Lupyan experiment (Lupyan, Rakison, & McClleland, 2007) there was the difference in categorization performance but not in RT rates. Thus our results seem to be right opposite to them – our groups differ in RT but not in the categorization performance. One of the possible explanations of that difference is the structure of our category ("chair") which was much more simple from the beginning. Participants knew which features they were to deal with (back, feet, seat). Category structure in the G.Lupyan experiment was more difficult – models of aliens with unlimited number of features. And so RT in their research was higher (more than 1000 ms). Thus a much more simple category structure in our research resulted to the same performance in all experimental conditions.

But our results seem not to be accidental considering findings of another G.Lupyan research (Lupyan, 2008) which showed the negative impact of the sign-label on remembering object's individual features related to common category. It seems that signs direct our attention to certain object's features relevant to sign meaning and force the categorization of a familiar object. But in the case of new objects such attention to familiar features disturbs refocusing of attention to new features. And that is probably the cause of increasing RT.

Our results showed that meaning of the sign has no full impact on performance and RT. But we have indirect results indicating that our induced meaning was still included in the categorization. We found that false memories effect significantly grows after concept tuning procedure and even become larger than effect for studied word (those which actually were in the list). These results tell us that meaning of induced words wasn't used in the concept learning but probably the category use itself actualized this meaning and forced the false memories effect.

In our research we found out that the meaning of the sign unlike the sign itself doesn't significantly influence the learning of category boundaries. We don't know yet how exactly the impact of the sign and its meaning is connected with different stages of concept formation in the course of learning. We can suppose that the impact of the sign physical properties should be connected with earlier stages of categorization and the impact of the meaning – with later stages. Also we don't know yet about interaction of the sign and its meaning with the category structure. It is known that categories with family-resemblance structure are not so strongly depended on the feedback as rule-based categories (see Sloutsky, 2010 for review). Probably the differences in the impact of the sign and its meaning would be larger in the rule-based categories than in the family-resemblance categories. Our future research should answer these questions.

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