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THE ROLE OF LABELS IN LEARNING STATISTICALLY DENSE AND STATISTICALLY SPARSE CATEGORIES

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THE ROLE OF LABELS IN LEARNING STATISTICALLY DENSE AND STATISTICALLY SPARSE CATEGORIES[5]

Subjects were given classic category formation tasks with feedback. We used two types of categories—statistically dense and statistically sparse. We conducted four experiments to assess the influence of sign type (experiment 1) and the interference of redundant actions performed with the sign (experiment 2) on the performance of learning different types of categories. We found that in the case of dense category formation, the visual distinction of the sign from other object features is more important. In the case of sparse category formation, easy verbalization is more important. Additionally we showed that verbal interference, directed at the actions with the sign, improves sparse category formation, but worsens dense category formation. The results of our experiments are discussed in accordance with the Competition Between Verbal and Implicit Systems (COVIS) model of multiple systems of categorization.

Keywords: categorization, concept formation, sign, category structure, learning.

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1. Introduction

Category learning is one of the basic cognitive functions of human beings. Categories help people to organize their knowledge about the world and to predict the properties of new objects. The ability to form new categories and to use them in cognitive processing is based on the implicit assumption that some objects share some common properties. The categorization rules people use in every-day actions are not homogeneous. For example, we distinguish dragonflies from butterflies on the basis of separate features, easily verbalized, such as big eyes or transparent wings. At the same time, our memory stores many examples of dragonflies and butterflies and allows us to classify a new object without the involvement of speech but through the comparison of this object with stored examples using all the features at once.

1.1. The theory of multiple categorization systems

The traditional psychological theories of category learning usually choose one organizational principle to explain learning and categorization, whether it is the memorizing of all category examples (Medin, & Shaffer, 1978), or finding the most predictive features (Bruner, Goodnow, & Austin, 1986), or computing the most frequent feature values (Rosch, & Mervis, 1975). Each of these theories describes different processes of categorization, so for now it seems impossible to assess their value and objectivity regarding each other. Under these circumstances the appearance of new theories based on the idea of multiple categorization systems (MCS) was inevitable. The position of such theories is justified, since categorization and perception, do not have to function within a single principle. The lack of such a principle can be filled by the work of several independent systems, which, nevertheless, work to reach a consensus.

The earliest, most complete and influential MCS theory is Ashby's theory of Competition Between Verbal and Implicit Systems (COVIS). In his early research Ashby (Ashby, Alfonso-Reese, Turken, & Waldron, 1998) found two relatively independent systems of building categorization rules: the implicit system (categorization rules are built on a principle similar to prototype formation, i.e. on the basis of the summation of a large number of surface features) and the explicit or verbal system (categorization rules are built on the basis of the extraction of a few relevant features). The launch of each system can be initiated by using objects with different frequency distributions of the feature values. Category examples can be very similar to each other in many features and such categories are called *dense*. Other categories are called *sparse* and have only few features in common. For example, prototype formation in the natural environment is a version of dense category creation because none of the object's features is the only relevant one. In his subsequent research Ashby found that the functioning of these category systems is impaired independently under different neurological disorders (Ashby, Noble, Filoteo, Waldron, & Ell, 2003). Also it is evident from COVIS that the implicit system evolved first and appears to be basic in animals, and the verbal system comes later and is limited to humans.

The MCS theory was used in the experimental psychological research of Sloutsky (Sloutsky, 2010) who suggested that those two systems start functioning at different ages. He named the systems: "compression-based" (which corresponds to implicit) and "selection-based" (explicit or verbal). The compression-based system appears probably from the birth and leads to dense category formation. The selection-based system appears much later (after the age of 5) and undergoes several qualitative changes during its development. These changes are connected, first of all, with speech, which demands not only an advanced ability for the cross-modal processing of information, but later the ability to use some object features (such as labels) but not the others (such as perceptual features) as indicators of category resemblance. Second, as the work of the selection-based system demands a supervised attention shift during category learning, it cannot operate properly without advanced executive function. Besides, as it results from such a description of MCS ontogenesis, the work of category systems depends on feedback to a variable degree. It was shown in Kloos and Sloutsky's experiment (Kloos, & Sloutsky, 2008) that both children and adults performed better in concept formation with feedback when categories were sparse (and, correspondingly, the selection-based system was used) and performed better without feedback when categories were dense (the compression-based system was used).

1.2. The role of speech in categorization

The MCS theory has many followers because it offers a convenient way of describing categorization: any of the multiple systems can be presented as an independent module specializing in a certain type of the task (Yamauchi, Love, & Markman, 2002; Hoffman, Rehder, & 2010), category structure (Miles, & Minda, 2011), or the availability of feedback (Maddox, Ashby, & Bohil, 2003). However other researchers claim that the MCS theory is only good at demonstrating the differences between categorization systems which can be easily reduced to specific brain areas (Love, 2013). For instance, the visual similarity of category examples indeed activates the visual cortex and the absence of such similarity forces us to deliberately shift our attention between features which requires a mature prefrontal cortex. Will the differences between categorization systems remain under other circumstances, not connected only to the difference between surface similarity of category examples?

The most interesting, from our point of view, is to compare how these two categorization systems deal with speech and language signs. Classic category formation research uses words only as a form of feedback, but modern research argues against that. Words strengthen visual differences between objects even when they are not used as feedback (Lupyan, Rakison, & McClelland, 2007). Words also prepare our perception for categorical tasks by evoking our expectations to see similar objects even before these tasks are given (Kotov, Vlasova, Kotova, & Agrba, 2012).

How important is speech for different systems of categorization? The answer to this question lies partly in the MCS theory: speech is not needed for the implicit system but it is necessary for the explicit system. But from our point of view this answer is not complete because there is no simple correspondence between the type of category and the presence of speech in real-life, non-experimental conditions. For instance, examples from natural categories, which usually come from the work of the implicit system (such as a dog) can be marked by names in some communicative situations but not in others. Moreover child’s lexicon develops most intensively from 2 years of age (Bloom, 2000) and till 5-6 years, the period when, according to the MCS theory, the system of explicit learning has not begun functioning. Thus, the other question appears to be more useful: exactly which properties of speech are important for the successful working of different systems of categorization? Considering that speech contains both perceptive (acoustic, visual) and non-perceptive (semantic, conventional) characteristics, we hypothesise that different characteristics will be important for different categorization systems in category formation.

2. Experiment 1a

We used a classical category formation task with feedback in all four experiments of our research. We evoked the implicit system of learning by using the dense distribution of feature values and the explicit system by using the sparse distribution. Our independent variables in each experiment were the properties of a sign, which also played the role of feedback in the process of learning. Thus, we can define which of those properties leads to more successful category formation in the two systems of learning.

In our first experiment we tested the hypothesis that the performance of the formation of the dense categories will be higher if the signs based on perceptive distinction, such as colour (perceptive signs), are used for the labelling of the two different categories. But the performance in the sparse categories formation should be higher if the verbal signs, differing in semantics, are used.

2.1. Method

2.1.1. Participants.

A total of 57 (41 female) undergraduate students at the Russian State University for the Humanities, Moscow, participated in the experiment to satisfy credit requirements for psychology courses. They ranged in age from 19 to 34.

2.1.2. Material

To evoke different categorization systems we made two sets of objects with different feature distributions, one for the dense categories and one for the sparse (Table 1). Features were the body parts of an artificial insect, resembling a dragonfly in shape. We used five features: legs, forewings, hindwings, abdomen and thorax. Each of the features could be one of two values (big or small). All five features varied in the dense categories so that objects from one category had at least four features with certain values (upper half of the table 1). Membership of the sparse categories was defined by a single feature value common for all category examples (lower half of the table 1) such as the length of the hindwings. All other feature values varied randomly. Thus, the generalization participants were to form had to include four features out of five in the dense categories and one feature in the sparse categories.

Table 1. Distribution of feature values in different types of categories. Bold numbers in the sparse category rows are the values of the relevant feature.

	Category A					***Category B***				
	f1	*f2*	*f3*	*f4*	*f5*	*f1*	*f2*	*f3*	*f4*	*f5*
Dense category structure	1	0	0	0	0	0	1	1	1	1
	0	1	0	0	0	1	0	1	1	1
	0	0	1	0	0	1	1	0	1	1
	0	0	0	1	0	1	1	1	0	1
	0	0	0	0	1	1	1	1	1	0
Sparse category structure	**0**	0	1	1	0	**1**	0	1	1	0
	0	1	0	0	1	**1**	1	0	0	1
	0	0	0	1	1	**1**	0	0	1	1
	0	1	1	0	0	**1**	1	1	0	0
	0	0	1	0	1	**1**	0	1	0	1

We used two signs for two categories of each type as feedback. The type of sign varied in two experimental conditions. The verbal sign condition had words for the sign. We told our participants that these words—*imperator* (the emperor) and *krasavitsa* (the beauty)—were the biological names for the two types of dragonflies. Those words differed in semantics (although the meaning was artificial) and subjects could read them on their own. For the other condition, perceptive signs, the signs were two dragonfly silhouettes of the same shape but different colour (red and green). This type of the sign was perceptive but not lexical because the difference between two signs was perceived, first of all, visually and did not contain any particular semantics. The size of the signs (words and images) was approximately the same.

2.1.3. Procedure

Each subject was assigned randomly to one of the four conditions defined by the combination of the category type (dense or sparse) and sign type (verbal or perceptive). The main task was to find the rule dividing all examples into two groups. The training series consisted of six blocks, ten objects each or five for each of the two categories (Table 1). The appearance of the examples inside each block was randomized. Thus, all subjects performed the standard classification task with feedback. The task was presented and the answers were fixed with the special computer program executed on a 15” monitor. Each block started with a white background presented for 1 second. Then the image of the category example appeared for 1,5 seconds. The image then disappeared, followed by the white background again, and a subject had up to 5 seconds to decide which one of the two categories that example belonged to. The subject answered by pressing one of two buttons on the keyboard. Whether he was right or not the subject was given feedback (category sign) for 0,5 seconds.

To estimate the learning efficiency, we summed the number of correct answers within a block, which could vary from 0 to 10, and then transformed them into probability evaluations for the processing needs. Thus, the performance at the chance level corresponded to 0,5. The subjects whose performance was at that level until the last training block were excluded from further data analyses (4 subjects).

The experiment was conducted by a mixed factor design 2x2x6: category type (dense and sparse categories, between-subject), sign type (verbal and perceptive signs, between-subject) and training block (six blocks, within-subject). All results in this and the three further experiments were processed with the analysis of variance with repeated measures (ANOVA). We could not compare the performance in the formation of the dense categories with the sparse categories performance as the formation of the dense categories required participants to remember and pay attention to all features, and the formation of the sparse categories required attention shifting from one feature to another, these difference in the structure and the content of cognitive operations did not compare the efficiency of the two systems of categorization. Thus we only assessed and discussed how much the performance changes in each system separately depending on the signs involved.

2.2. Results and discussion

The categorization performance depended on the sign type for the dense categories—the performance was much higher with the perceptive sign than with the verbal sign, $F(1, 34)=8.45$, $p<0.01$, $\eta^2_p=0.32$ (Fig. 1, left). There were no significant differences in the performance in the sparse categories depending on the sign type, $F(1, 21)=0.59$, $p>0.1$ (Fig. 2, right). The analysis of variance also showed the significant impact of the training block factor for each category type, $p<0.001$ (Fig. 1), so that the learning exceeded the performance at the chance level in each case and was, as a whole, successful for the given task and material.

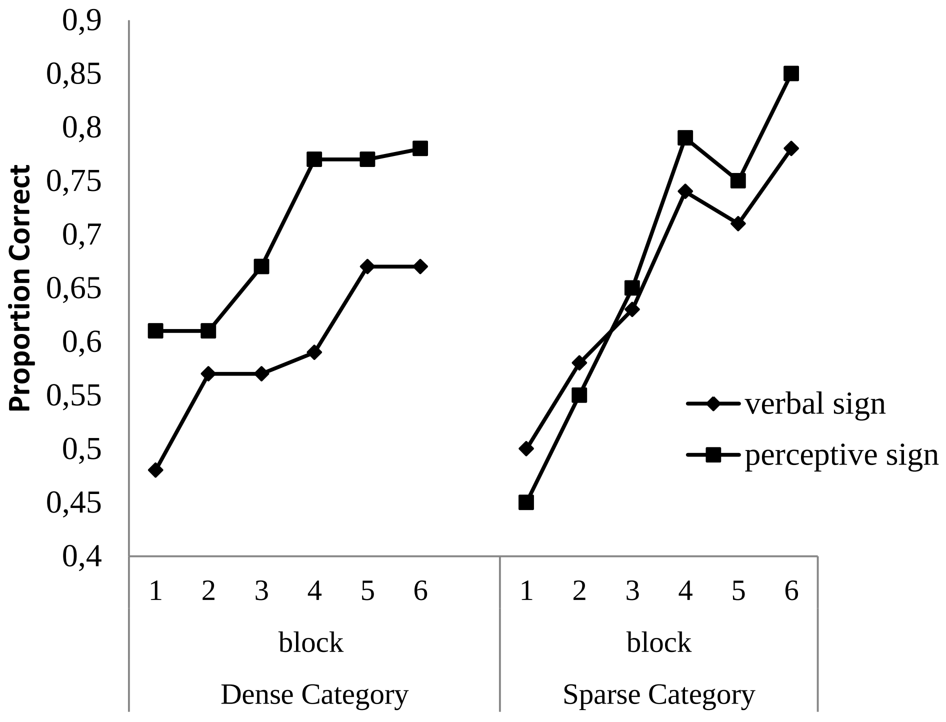

Fig. 1. Average performance at each block for each category type and each sign type

Our hypothesis, suggesting that the sign type has the opposite impact on the formation of different types of categories, was confirmed partly. Indeed, the participants were much better at forming the dense categories with the perceptive sign than with the verbal sign. The colour difference between signs, probably, provided an additional link with the object’s visual features and all those features were processed by the implicit categorization system together. But the word as a sign probably demanded additional processing because of its semantic load.

We did not find significant differences in the performance of sparse category formation depending on the sign type. This result does not agree with our hypothesis as we suggested that verbal signs but not perceptive ones should be relevant for the explicit, or verbal, system. On the other hand, however, a possible explanation could be the naming, as many participants did to themselves during the sparse category formation, as we found out from their reports at the end of the experiment. That is, the participants from the sparse category condition verbalised the image sign as “red” or “green” while the participants, forming the dense categories, verbalised it very rarely. We suppose that the objective form of the perceptive sign was substituted with a subjective one, more convenient for the subject, and so the sign became verbal. To test this we conducted an additional experiment with a new perceptive sign, the appearance of which was symbolical but inconvenient for spontaneous verbalization.

3. Experiment 1b

To pick signs with a new shape we used a set of old Cyrillic and Latin fonts. We chose two signs which were the hardest to verbalize, since they least resembled the letters of modern Cyrillic or Latin alphabets and were unknown to the subjects. According to our hypothesis, this difficulty in spontaneous internal verbalization of the sign should reduce the performance in the category formation for the sparse categories.

3.1. Method

3.1.1. Subjects

A new group of 38 (18 female) undergraduate students at the Russian State University for the Humanities, Moscow, participated in the experiment to satisfy credit requirements for psychology courses. They ranged in age from 17 to 28. We compared the data of that group with the data from the previous experiment.

3.1.2. Material

The material for category formation was the same as before, only the form of the feedback was changed. We used two symbols from rare alphabets, which were confirmed to be unknown to the subjects (Ѭ and Њ). We further refer to these signs as unverbalized.

3.1.3. Procedure

The category forming procedure was exactly the same as in the experiment 1a. After the category formation stage we asked subjects to draw those unverbalized signs (from memory) and answer a few questions such as whether they wanted to name those signs and if so how, and also whether it was difficult for them to use those signs (as feedback). Those subjects who could not remember the signs were excluded from further data processing. We used the unverbalized signs both for the sparse category (the experimental condition) and for the dense category (the control condition). The control condition allowed us to test our hypothesis that the simultaneously processing of the features by the implicit system of learning is only possible when all the features have visual but not semantic differences. The use of the unverbalized sign should, nevertheless, induce adult subjects to treat them as speech components and not as simply visual images.

3.2. Results and discussion

We found significant differences in the performance in the sparse category formation depending on what type of the sign was used, a word (verbal sign) or a coloured image (perceptive sign) on the one hand, and the unverbalized sign on the other. For the latter, the performance was significantly lower on the last three training blocks, $F(1, 27)=12.94$, $p=0.001$, $\eta^2_p=0.32$ and $F(1, 28)=7.19$, $p=0.01$, $\eta^2_p=0.21$ respectively (Fig. 2, right). In the case of the dense category the difference in performance was only between the unverbalized sign condition and the perceptive sign condition, $F(1, 36)=11.46$, $p<0.01$, $\eta^2_p=0.24$ (Fig. 2, left).

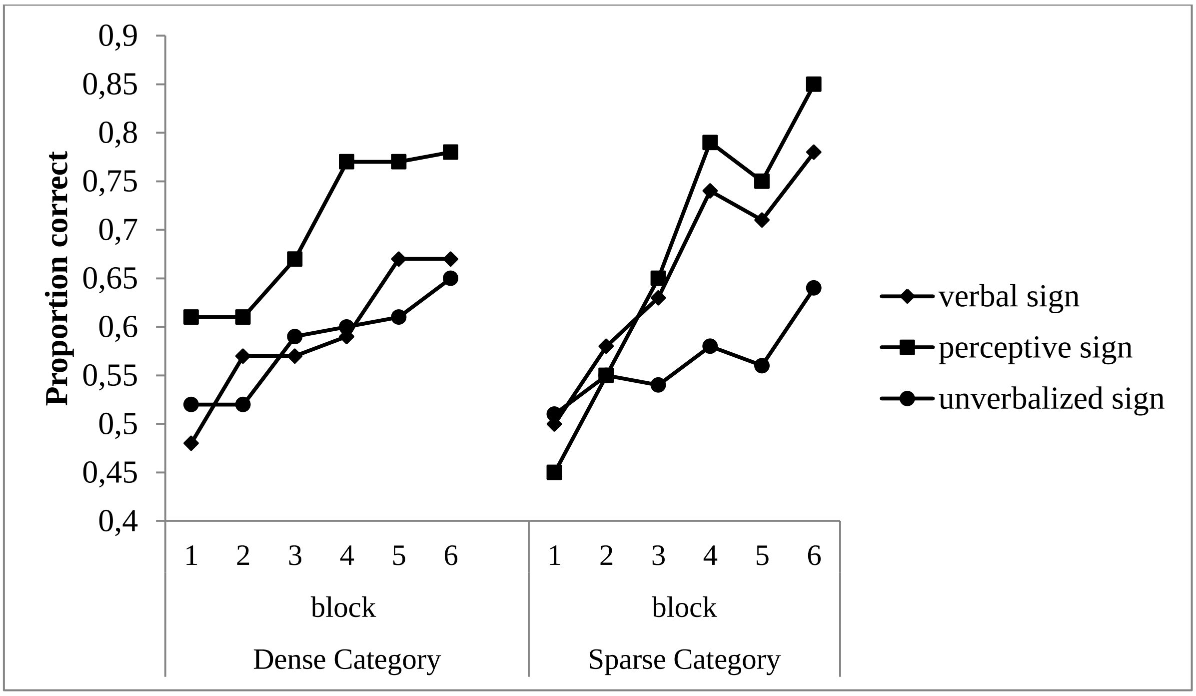

Fig. 2. Average performance at each block for each category type and each sign type (with unverbalized sign condition).

Our hypothesis that there is an additional internal verbalization of the sign, necessary for its use in the explicit system of learning, i.e. in the sparse category condition, was verified. The results of the experiment 1b show that the use of an unverbalized sign reduced the category formation performance.

Considering the work of the implicit system of learning, i.e. dense categories (the control condition), we can see that the use of unverbalized signs also led to a lower learning performance compared to the use of perceptive signs. The performance of learning with the unverbalized signs was the same as with the verbal signs. According to the subject reports, most of them saw the new signs as letters of some alphabet, even if they had never seen them before. In other words, they treated them as features of a symbolic nature and that troubled the perceptive correlation of those features with the others.

Why does the symbolic character of the unverbalized signs not help in the forming of the sparse categories and the explicit system of learning as a whole? We hypothesise that the functioning of the explicit system is not just regulated or launched by the feature frequency in objects but also requires some means of attention control, separate from the features themselves. The words, undoubtedly, work as a means of control, as they are perceived by subjects as something that indicates the purpose of learning and draws attention to the difference between the generalizations.

Speech, however, as an evolutionarily newer learning tool, also has newer constraints on its functioning. One such constraint is its physical shape, i.e. articulation. The main function of speech is communication and this function demands the possibility for (sub)vocal articulation, which is why, as we suppose, that demand should be partly kept for categorical learning: only those words which are convenient for the explicit system could be articulated in the case of a growing load on attention.

The word's form, convenient for articulation, is more important for the explicit system, than for the implicit one. The implicit system picks out common features among the objects with strong external resemblance. And the explicit system picks out common features among objects with great variability in their appearance. Which is why it is better tuned to the fast attention shifts towards new information than the implicit system. If the word has a new and unused articulary form, then part of the attention will be spent on it in prejudice of the search for the relevant features.

For example, if the subjects wanted to name the unverbalized signs, marking two categories, it would be an additional task for the explicit learning, competing with the categorization task. This is true only for those cases of articulation when the chosen name is unknown and the verbalization is not automatic. The second experiment showed that the concurrent task, demanding verbalization (for example remembering a set of numbers, appearing before each category example, to define later whether the target number was in the set) troubles category formation when the explicit system is working. But it does not happen with the implicit system (Miles, & Minda, 2011). We, in turn, suppose that such results should be observed even in simpler cases, for example, when we give subjects a new sign, marking the category, and ask them to say its name aloud every time a new category example appears. Such vocalisation, although not related to the other task (as in Miles & Minda's experiment (2011)), nevertheless will interfere with category learning. Such structured interference should take place only with the explicit learning system, not the implicit one. The implicit system does not require any means of attention control and additionally verbalizing a new sign will not interfere with category learning.

4. Experiment 2a

In the Experiment 2a we asked subjects to additionally verbalize a new sign (to themselves) during the whole learning procedure. This verbalization was an interfering task. We hypothesise that it would lower the performance of the sparse category formation and have no impact on the dense category formation.

4.1. Method

4.1.1. Subjects

A new group of 36 (21 female) undergraduate students at the Russian State University for the Humanities, Moscow, participated in the experiment to satisfy credit requirements for psychology courses. They ranged in age from 17 to 30. We compared the data of this group with the data from the Experiment 1a.

4.1.2. Material

The material was the same as in Experiment 1b.

4.1.3. Procedure

In addition to the category forming procedure we asked our subjects to say to themselves the “name” of the category signs (Ѭ or Ѣ) as soon as the sign appeared on the screen. We picked the name based on some distant outward resemblance to letters of the Russian alphabet: [zhi] and [yur]. The sign (Ѭ or Ѣ) appeared on the screen as feedback after the subjects chose the category for the next example. To make sure that subjects did not forget to say the sign’s name to themselves, we conducted a training session before the experiment: the subjects had to say the names aloud and as fast as they could, when the signs appeared on the screen one by one. And we also kept reminding them to say the sign’s names to themselves at each trial after each training block. We also extended the procedure to ten training blocks to find significant effects because the performance on first three blocks has almost no difference for any conditions and does not exceed the chance level.

4.2. Results and Discussion

The analysis of variance showed significant differences in the performance of the sparse category formation with and without additional verbalization, $F(1, 35)=9.95$, $p=0.02$, $\eta^2_p=0.15$. Although not very strong, this difference shows that subjects almost did not form the category in the condition with additional verbalization (Fig. 3), the learning curve only rises to the 0.56 level by the tenth training block—practically chance level. Another pattern was found in the dense category condition where there were no significant differences from the no-verbalization condition (p>0.1) and the learning curve had a normal shape, i.e. it rose from the first training block to the last.

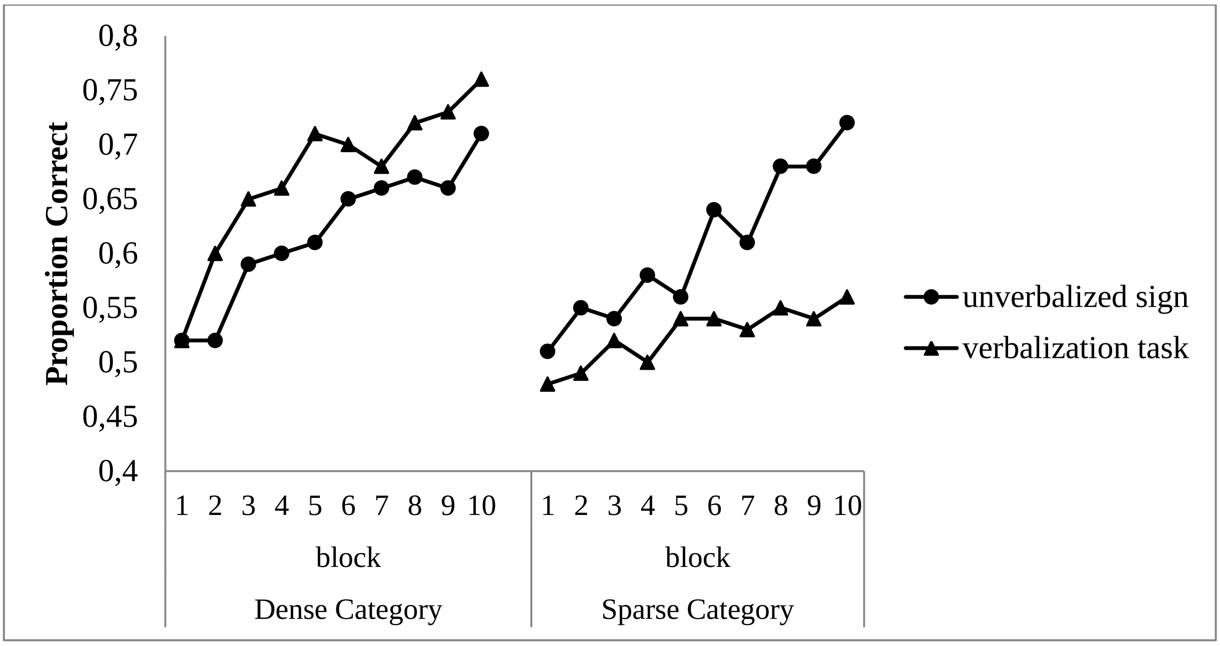

Fig. 3. The performance of the dense and sparse category formation with an additional loading onto the sign control.

Thus we showed that the use of verbal signs in sparse category formation and explicit learning differs considerably from the use of the sign for dense category formation and implicit learning. If the unautomatic articulation of the new signs did not lead to a decrease in the performance of dense category formation, the verbal signs in the explicit learning only allow the successful definition of the categorization rule when they have a convenient verbal shape which does not distract from the task.

An alternative explanation of these results, however, could be the vulnerability of the sparse category forming process to any interfering tasks, not necessarily verbal. In order to control for this, we carried out a fourth experiment including the interfering task with a sign but the task itself was nonverbal.

5. Experiment 2b

For this experiment we shifted the sign’s outward appearance and its verbal form. The subjects saw on the screen the syllables [Zhi] and [Yur] (in Russian letters) as the signs and should have imagine their iconic shapes in mind. Thus they still were given an additional task, but, from our point of view, this nonverbal task should not reduce the performance in sparse category formation, or in the dense. Since the subjects were given a convenient verbal form as the main sign (syllables they can read automatically), the sign in its turn will be able to perform its function and any additional manipulation with the sign (such as imaging the visual forms) will be structurally irrelevant to the main task and so will not lead to a drop in performance.

5.1. Method

5.1.1. Subjects

A new group of 40 (15 female) undergraduate students at the Russian State University for the Humanities, Moscow, participated in the experiment to satisfy credit requirements for psychology courses. They ranged in age from 18 to 27. We compared the data of this group with the data from the experiment 2a.

5.1.2. Material

The only difference from the previous experiments was in the feedback: this time we used syllables [Zhi] and [Yur] to mark each of the two categories. The syllables were of the same size and appeared on the screen for the same time as the previous feedback images did.

5.1.3. Procedure

Before the main session the subjects were trained to imagine the iconic shapes (ЊЖ and Њ) in response to the syllables’ appearance ([Zhi] and [Yur]) on the screen (the imagination task condition). They could only begin the main session when they drew such shapes correctly (from memory) after ten training blocks. We also kept reminding our subjects to visualize those signs during the main session. But it was still hard to control whether they really did the visualization, therefore we unexpectedly asked them to draw the signs again after the tenth training block in the main session. The subjects who formed categories successfully but were unable to draw the signs correctly were excluded from further data processing Therefore data were eliminated for two participants (5%).

5.2. Results and discussion

We did not find any significant differences in the performance of dense category formation between the verbalization and imagination task conditions, p=0.78 (Fig. 4). But the performance between those conditions differed significantly in sparse category formation, $F(1, 35)=12.27$, $p=0.001$, $\eta^2_p=0.26$. Subjects were much better at forming categories in the imagination condition than in the verbalization one.

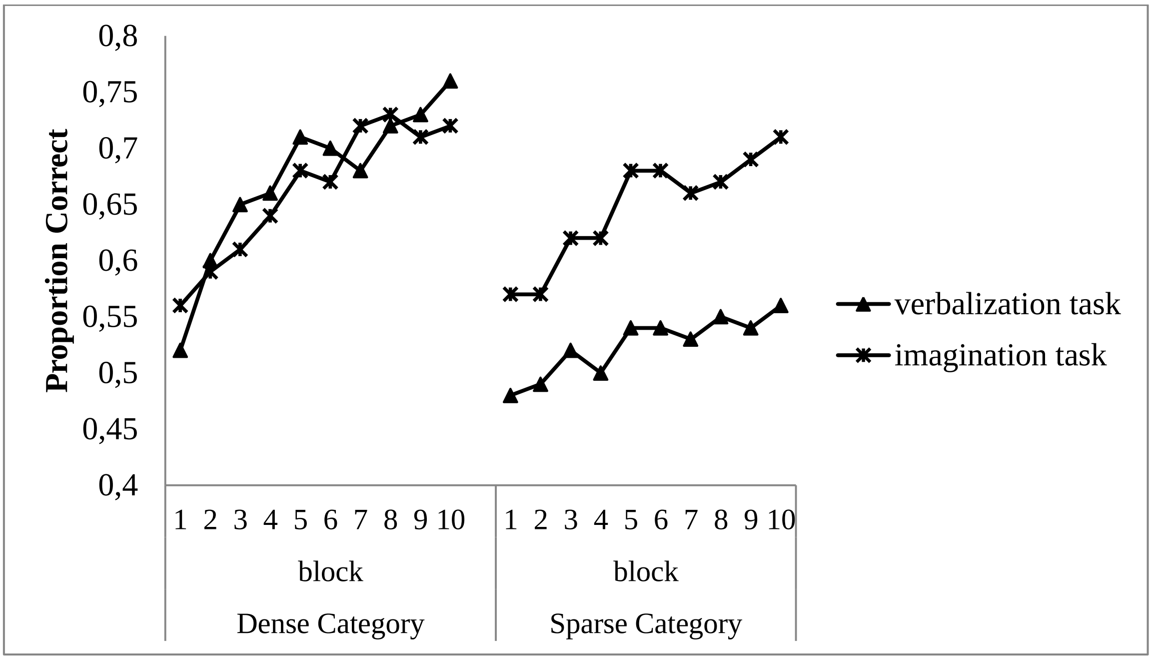

Fig. 4. The performance of the dense and sparse category formation in the verbalization and imagination task conditions.

Thus, we showed that the lowering of the performance in the conditions with additional verbalization could not be explained just by the general mechanism of interference to which the explicit system of learning is so vulnerable.

6. General Discussion

By changing the different properties of the verbal signs and different actions with the signs through the four experiments, we demonstrated the different functions signs could perform in the formation of different types of categories. We found that visual characteristic distinctions of the signs (colour) were more convenient for dense category formation whereas the verbal form (the possibility of verbalization) was more important for sparse category formation. At first sight, these results correspond well to the main statements of the MCS theory and other experimental results in the MCS context. For example, one experiment with pre-schoolers showed that they, unlike adults, could not separate a word from the object's other features and perceived it as an equivalent feature (just one of the features) (Deng, & Sloutsky, 2013). In an induction task, the category label was pitted against a highly salient feature, such that the reliance on the label and the reliance on the salient feature would result in different patterns of responses. The results indicate that children rely on the salient feature when performing induction, but not on a category label. That is, if the implicit system of learning is the only one available for children of this age, verbal signs will be included in the generalization along with object's other features.

However, we found additional data that could not be derived from the MCS theory. For example, the subjects, being given nonverbal signs during sparse category formation, spontaneously verbalized them (Experiment 1a). But in the case of dense category formation, the performance in the condition with unverbalized signs differing notably from the object's other features, was all the same lower than in the condition with signs differing in colour (experiment 1b). These results altogether pose a question the MCS theory cannot answer: what property of an object or a sign will or will not be a feature? This question does not concern the involvement of attention—whether the subjects will notice this property or not, but of a different relation and different actions with these features during the formation of the different types of categories.

In the second experiment (2a) we showed that at the low automaticity of the correlation of the sign (symbols) and its artificial name (syllables) the performance of sparse category formation reduces in contrast to dense category formation. The power of interference from the articulation of a new name during sparse category formation was even stronger than in the Miles and Minda's experiment (2011), because our subjects were unable to form the category even in the last training block. This fact is especially notable since the interference in our experiment only began to work at the end of the trial when the feedback appeared, unlike the Miles and Minda's experiment where the interference lasted from the perception of an example to the end of the appearance of feedback. It is also interesting, that in the Miles and Minda's experiment the interfering task demanded not saying numbers to yourself but imagining a geometrical pattern, lead to a symmetrical worsening of dense category formation, but that did not happen in our experiment (2b). We suppose the reason for such differences to be in our discovery of not just the dependence of category formation on the properties of the sign, but of the exact moment during the learning process when this dependence appears. In the case of the dense categories and the implicit learning, the initial stages, where the information about the visual features is collected, are more important than the results of the hypotheses testing after feedback, that is why the interference from the tasks demanding the imaging of additional space-visual patterns will only work when it accompanies these initial stages.

6.1. Conclusions

Category formation is a difficult task for the human cognitive system. Signs and words help to solve this problem, but with different types of categories the help goes in different ways. Why is it that the visual discrimination between an object's features and sign's features is so important for dense category formation, and the opportunity for easy verbalization is important for sparse category formation? Apparently, it is related to the different structure of cognitive operations included in the category formation process. This suggestion underlies MCS theories, such as COVIS. However, at present there are not enough data considering what exactly makes these operations different from each other. Our research is the first to show this distinction by way of the relation of the category with the properties of different signs and actions with those signs. Further research is needed for a deeper investigation into this relation. Many more questions concern dense category formation. It is yet to be explained why subjects prefer not to verbalize category names in the dense category formation process. Is there interference related to the perception of a sign in dense categories and if so, what could be its nature? It is also necessary to investigate at what stage of the perception of category example and taking a decision about category membership does the interference work in dense category formation.

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