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Students' Abilities in Explanation and Elimination of Thinking Biases

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Abstract: The article presents the results of experimental research of students' way of thinking at solution of classification problems; considers fulfillment of the operation of comparison using verbal materials, as well as the ability of students to improve solutions jointly or individually; shows the existence of stable structures-biases being deviations from the logical standard of comparison, in the students' thinking; distinguishes the types of biases of various structure; shows the role of reflexion based on logic knowledge in the development of the classification thinking of students; and suggests a modification of the R. Olver and R. Hornsby methodology, which allows to study the comparison of students' unity of cognitive and metacognitive elements.

Key words: Comparison · Logical form of an operation · Metacognitive processes · Reflexive reasoning · biases · Bias structure · Correction of comparison mistakes

INTRODUCTION

Inclusion of second level cognitive processes, or metacognitions, in the psychological research subject is one of the most important scientific trends. The beginning of studying metacognitive processes is usually associated with the name of Flavell [1]. Unlike cognitions, metacognitions are not oriented to the real world items, but to the cognition itself, the methods of cognition and knowledge. It becomes even more obvious that the study of thinking and intelligence cannot be limited to evaluation of the result and the process of problem solution. Metacognitions are involved when some difficulties or failures in the course of problem solution occur and they provide evaluation of the used strategies, goal-orientedness and organization of mental activity. Metacognitive processes also actualize in situations when an individual is to reason his solution or choice of an alternative [2].

In the Russian science, this method is most consistently developed by M.A. Kholodnaya. In the concept of intelligence developed by her, the metacognitive experience structures ensure involuntary and voluntary regulation of intellectual activity by controlling the processes of information processing and by using individual intellectual resources. The ideas of metacognitive learning have become popular in the Russian education [4].

Initiation of metacognitive processes is the factor of success in various spheres of practice, from teaching the most complex types of intellectual activity to correction of development disorders. The metacognitive support is important at studying the elements of scientific discovery thinking [5]. Metacognitive monitoring plays a positive role at evaluation by tested children of their intellectual test results [6]. The low anticipation consistency and specific anticipation mistakes revealed with the children who have speech pathologies [7] set a special target of correction, by which the initiation of metacognitive processes can improve the overall intellectual development. The thinking acts, due to which students use humor as a coping strategy, allow to proceed to more adequate methods of situation solving, transform emotions and create psychological experience of the success [8]. Such intuitive assessment of the mode of action or considerations in situations difficult for an individual can hardly be considered from the perspective of cognitions and metacognitions.

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The metacognitive approach has revealed new aspects of the psychological experiment procedure. M.J. Roberts studied how directions formulated in different ways focus the attention of a tested person on details that are not important for the problem solution and the methods of its solution and encourage him to choose a variant in spite of its logical consistence [9]. A separate subject of cognitive research is the specificity of joint solution of a problem, for example, at a professional education of students. Researchers acknowledge the value of the discussion space for solution of a problem in the education practice. However, joint work does not reveal the contribution of each particular participant into the creation of a product and the roles of cognitions and metacognitions in the solving process [10]. Experimental procedures are needed, which can unveil the individual methods of problem solution and their transformation during joint work.

The Russian science has its own tradition of studying the realia, which the cognitive science associates with metathinking. A.V. Karpov distinguished about ten authentic directions of studying reflexion and reflexivity [11]. L.S. Vygotsky was one of the first scientists who showed the role of reflexion and comprehension in the development of the thinking of a child [12]. Reflexion and comprehension, which are inseparably associated with the thinking, differ from it by the subject matter. The classical metacognitive approach determines the reflexivity measure as an individual style peculiarity of cognition. At that, the internal form of reflexion, which must be different in different situations of cognition, is not revealed. On the opposite, the cultural and historical approach treats reflexion from the perspective of its logical form. L.S. Vygotsky finds awareness and reflexivity of terms meanings in the system subordinated to the hierarchy of genus and species be the most important attribute of conceptual thinking. The infantile forms of generalization (biases) described by him are in fact the disorders of the hierarchic structure of genus-species relations in their essence. At studying scientific disciplines at school, where the classifications are based on the category of genus-species relations, conceptual generalization substitutes biases. V.V. Davydov believed substantial reflexion to be a typological property of theoretical thinking, the thinking about thinking, based on dialectical logic [13]. P. Tulviste [14] supported L.S. Vygotsky and showed again that the basis of reflexion at systematic scholar education is the logic knowledge being the knowledge about the thinking itself.

It is crucially important, what method a pupil uses to perceive this logic knowledge. At studying scientific classification systems, the standards of comparison, classification, etc. can be formed as a byproduct. The logic form of the operation can remain outside the education focus at that. In other cases, the logic of classes is a specialized study subject included in the formal or mathematic logic course at higher educational institutions. Various school disciplines (mathematics, native language and others), which pretend to develop the pupil's intelligence, start including elements of the logic of classes.

When studying the methods of grouping using verbal and non-verbal materials, J. Brunner and his associates discovered new types of biases, including the structure of a key ring [15]. According to it, by the age of 19, biases almost disappear from students' answers; they are replaced with correct hierarchic structure of similarity.

The pilot study that we carried out revealed a considerable number of biases at solving similar problems by Russian students. At the original hypothesis, the appearance of biases was associated with the poor attention of the tested persons. It was assumed that after an additional discussion the tested persons would reveal and eliminate them systematically.

MATERIALS AND METHODS

For the purposes of the research, we modified the *Formation of Equivalence Groups of Verbal Material* methodology: The source version of the methodology suggested a set of tasks to determine similarity and difference in an extending sequence of words: "*banana, peach, potato, meat, milk, water, air, bacterium, stone*". The first question was: "What is the similarity between a banana and a peach?"; the second: "How do a banana and a peach differ from a potato?"; the third: "What is the similarity between a banana, a peach and a potato?" and so on. Totally, there were 14 tasks (7 of them targeted determining the similarity and 7 – determining the difference) [15]. Almost all tasks have several correct solutions. The tasks become more difficult as the number of words increases, which allows differentiating the tested persons by the extent of their proficiency in the comparison operation.

The goal of the modification that we made is to identify the cognitive element of the problem solution (fulfillment of the comparison operation) and metacognitive elements (control and reflexive evaluation

of the initial solutions, search for and analysis of the made mistakes, explanation of the essence of the mistake). The biases in individual answers were useful for improvement of solutions and became the subject matter of new problems.

The experiment procedure included four stages. The first stage was the individual solution of a series of comparison tasks. The direction required to provide several answers to each task and highlight the most suitable one. The second stage was the joint search for the best answer in pairs, which were randomly arranged between the participants of the first stage. The task was to discuss the individual answers, select (work out) the best mutual solution and substantiate its advantages. The third stage was the evaluation of three variants of solution of a single task. At that, the task to find the similarity of the row "*banana, peach, potato, meat, milk, water, air*" was used. Three statements of similarity were selected from the answers of the tested persons at the first and second stages: "all of them contain air"; "these all can ensure the vital activity of a human"; "these all – meals, water and air – are necessary for a human". All of these are answers to biases of various structures. These biases stably repeated in individual and joint answers and remained unnoticed when discussing in pairs. The directions suggested evaluating the correctness of these solutions. At the fourth stage, it was required to restore the standard comparison structure. The task of the third stage was suggested again, but it was mentioned that all three answers were wrong. According to the directions, these three answers were received from pupils in the class and the task was to identify the mistake and explain the essence of the mistake to the pupil.

The tested persons were the senior university students; there were 144 students at the first stage, 108 students (59 pairs) at the second stage and 96 and 59 – at the third and fourth stages, respectively. All of them studied formal or mathematical logic.

RESULTS

Stage 1. We received 3468 answers to the 14 comparison tasks. 2016 of them were acknowledged the "best". The share of biases among all solutions equaled to 18.4%; and there were much less of them among the "best" answers – 11.6% (the difference by the [CHI]-Pearson Square criterion is valid to the $p<0.001$ extent). The biases were also present in the solutions of most tasks. The examples of biases in the answers of the tested persons are: For the question "What is the similarity between *a banana, a peach, a potato?*": "they all need to be skinned", "their shape is similar", etc. For the question "What is the similarity between *a banana, a peach, a potato, meat, milk and water?*": "all of them contain water"; "all of them are necessary for humans"; "all of them produce vitamins for humans", etc. All the provided answers breach the comparison standard – the attribute, which is called distinguishing, is not associated with every compared word. For the question "What is the similarity between *a banana, a peach, a potato, meat, milk, water and air?*" the following biased answers were received: "we can hold all of them by hand, except for air"; "we can eat all of them, except for air", etc. In all answers, the attribute, which is to exclude the individuum from the class, is not exclusive for the members of this class. At the second stage, after discussion in pairs, 1008 joint solutions were given, which were assessed as the "best"; 18.2% of them were biases. The share of biases in the joint answers almost reached the level of "all answers" in the first series.

The tasks of the third and fourth stages were more oriented to the initiation of metacognitive processes, than those of the first and second stages were. The subject of metacognitions in this case is the three biases of various structure, which are to be compared to the standard structure of the comparison operation. The first one is the structure of a key ring (Figure 1). One of the members of comparison was wrongfully used as a common attribute, which disregards the similarity hierarchy.

In the second answer, instead of the comparison operation in its function as the search of a common attribute or inclusion in the same class, the *Part-Whole* relation was set (Figure 2). The attribute "to provide vital functions", which can be associated with all members of the sequence as a whole, cannot be associated with each of them individually as the logic standard of comparison requires.

The third answer was given as a result of introduction of an intermediate group – meals – and the suggested criterion of similarity can be associated with the group, but not with the original subjects of comparison (Figure 3).

At the third stage, the minority of the tested persons noticed deviation from the comparison standard in the suggested answers and there were even less people who explained the deviation correctly (Table 1). 63.5% identified the structure of a key ring as a mistake and 4.1%

All of these items contain air

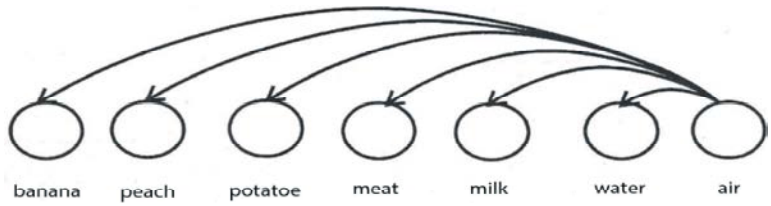

Fig. 1: The structure of a key ring instead of a similarity hierarchy

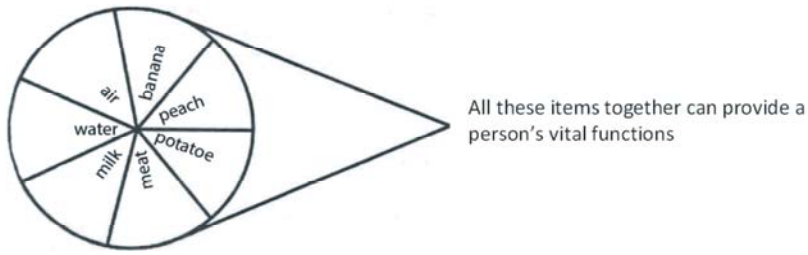

Fig. 2: The *Part-Whole* relation instead of similarity

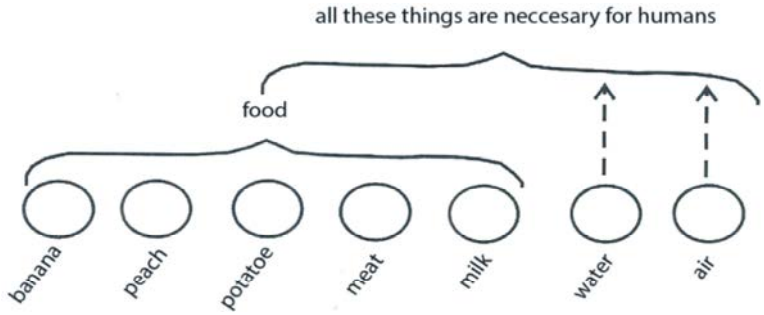

Fig. 3: Introduction of an intermediate group, which violates the similarity hierarchy

Table 1: Rate of success of the tested persons at evaluating the violation of the logical form of the comparison operation

	Failed to identify the violation (%)		Explained the mistake correctly (%)	
Bias type	Stage 3	Stage 4	Stage 3	Stage 4
The structure of a key ring	36.5	8.5	4.1	23.7
The *Part-Whole* relation instead of similarity	79.2	8.5	6.2	32.2
Introduction of an intermediate group	62.5	3.4	21.9	64.4

managed to explain it. 20.8% qualified the *Part-Whole* relation being a violation of the comparison standard and 6.2% explained it correctly. 37.5% said the answer, which introduced the intermediate group, was wrong and 21.9% managed to describe the mistake. These data show that the majority of students cannot identify the violation of the logical form the comparison operation.

If it is noted directly that each of the three answers is wrong, the quality of solutions fairly improves (the differences between the third and fourth stages of all indicators by the [CHI]-Pearson square criterion are valid at the $P<0.001$ level). Despite the direction, 8.5% of the tested persons failed to identify the first and second biases each as a mistake and 3.4% failed to identify the third bias as a mistake. There were considerably more answers, in which the tested persons managed to explain the subject of the mistake, than at the third stage. Comparison of the results of the fourth stage with the previous ones proves that these are the situations of search for a mistake in a "student's" work that actualize metacognitive processes with the students, based on the knowledge of the logical standard. At that, the ability to substantiate reflexively the subject of a mistake is still falling behind. Such reasoning cannot be provided just using intuitive comparison; the logical standard of an operation is to be reflected and verbalized. Without this,

it is impossible to describe what the own structure of each bias resides in and how it differs from the standard structure of the comparison operation.

The structure of the key ring was most often identified as a mistake at the third stage (63.5%). Among them, only 4.1% identified the violation of the comparison standard and the rest 59.4% argued the actual content of the answer, but not the logical form ("I disagree that the listed items contain air"). The second answer, in which the similarity was substituted with the *Part-Whole* relation, was called wrong by 14.6% of the tested persons; 6.2% managed to substantiate this substitution reflexively. The majority of the tested persons ignored the logical operator *All Together*, which determined the *Part-Whole* relation. Most often (28.1%), it was the third bias that was identified as a comparison standard violation, not just as an actual mistake. Of them, 21.9% noticed that the suggested similarity criterion was not associated with each of the members of the source sequence, but with the introduced intermediate sub-class.

At the fourth stage, the share of students who agreed that the answers contained a mistake increased considerably. However, more than half of the tested persons managed to explain correctly only the *Part-Whole* relation, which was used instead of the similarity relations. Less than one third of the participants explained what the deviation from the comparison standard in the structure of the key ring was. 64.4% managed to explain the essence of the mistake in the answer, which introduced intermediate groups and that was the biggest success. At the same time, this answer was least often admitted correct. In spite of the directions, a part of students failed to see any comparison standard violation in the suggested answers (8.5%, 3.4% and 8.5% in the three tasks). In the minutes, we encountered requests from the tested persons that asked to explain what the mistake, which they had failed to reveal, was.

Summary:

- Violations of comparison (biases) were revealed in the solution of the tasks to identify similarity and difference in the verbal material by senior students of a university who had passed the courses of formal and mathematical logic.
- The largest share of biases was revealed in the solutions suggested by students; it was less in the answers, which were marked as the best and increased again in mutual solutions.
- Three types of biases of various structure, which were the most popular among the students' answers, were identified: the structure of a key ring, the establishment of a *Part-Whole* relation instead of similarity, the introduction of intermediate groups.
- Despite generally the share of the structure-biases was not large in the total of operations completed, they are rather stable. These biases are not always qualified by students as violations of the comparison standard, even when it is directly specified in the direction.
- Substitution of the correct (hierarchic) structure of similarity with other structures is not obvious for students. The structure of comparison is not sufficiently differentiated by them from other structures, which reflect different types of relations. In the hardest cases of mistake analysis, the tested persons did not indicate good knowledge of the comparison structure, without which reflexive control as a means of accurate fulfillment of a comparison operation is impossible.
- The reflexive description of a bias as a structure, which does not comply with the standard structure of a comparison operation, falls behind the ability to qualify biases as mistakes.
- Students showed the best results in describing the biases' structures in the situation, which simulated explanation of the essence of the comparison mistake to a "pupil".
- The situations of revealing, analyzing, explaining and trying to correct the mistakes (their own ones, or those of one's partner student and a pupil) have better diagnostic capacity, than comparison does, for evaluation of the level of students' proficiency in this operation,
- The made modification of the methodology allows to reveal the peculiarities of both cognitive and metacognitive elements of the solution of comparison tasks, or, being more precise, to describe the level of students' proficiency in this operation.

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