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Conceptual structures, conceptual abilities and productivity of cognitive functioning: the ontological approach¹

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Abstract

The main disadvantage of functional approach is that it does not allow us to move from the level of descriptive analysis to the understanding of the holistic ontological nature of intelligence. We offer to pass from the functional approach to the ontological one. The main issue of our research was to discover the nature of conceptual structures which from inside determine the essence of intelligence. Participants of the experiment were students aged 14-22 years. The diagnostic complex included the assessment of conceptual structures, conceptual abilities, creativity, intelligence, field dependence/field independence, impulsivity/reflectivity. Research design consisted of two independent parallel series of studies with different psychodiagnostic tools, participants and research objectives (everyday concepts "Soil" and "Illness" and scientific concept "Substance"). Nevertheless, the similar results was obtained: the higher is the level of conceptual structures, the higher is the level of conceptual thinking, field independence, reflectivity, creativity, intelligence, competence and successfulness in real professional activity. Based on results obtained, we believe that the ontological approach to psychological research can make a worthy alternative to the functional approach.

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1. Introduction

The specificity of psychological cognition is that the researcher deals with the external manifestations of certain mental phenomena. The inner nature of these phenomena is not available for direct psychological analysis. The consequences of such state of affairs in psychological research are dramatic. The definition of mental phenomena in terms of their properties leads to an inadequate methodological position. For instance, personality is defined as a set of traits; intelligence is a catalog of cognitive functions.

The main disadvantage of functional approach is that it does not allow us to move from the level of descriptive analysis to the understanding of the holistic ontological nature of intelligence. We offer to focus on the issue of the nature of mental formations which from inside determine of the numerous and various manifestations of intelligence.

How to pass from the functional approach to the ontological one? We believe that a structural analysis could provide a substantial assistance in solving this acute problem.

1.1. Ontological approach

According to the ontological paradigm mental phenomena should be considered as mental structures with the specific laws of its organization and its functioning (Vekker, 1998; Chuprikova, 2007; Kholodnaya, 2002, 2012; Volkova, 2013, 2014).

First, any mental phenomenon has a structural base which operates as a real existing mental structure consisting of components in their certain interrelationships. From this point of view, the characteristics of composition and structure of mental phenomena come to the fore in psychological research.

Second, the properties of any mental phenomena are related to the features of its structural organization. Therefore, mental properties should be explained in terms of the composition and structure of their mental substratum.

Third, mental structures are accumulated (integrated) forms of mental organization, since the formation of each subsequent structure is carried out on the basis of accumulation (integration) of elements of the preceding structures.

Fourth, mental structure is built of certain psychic material. Various types of modalities of mental experience (verbal-speech, visual, kinesthetic, proprioceptive, and sensory, emotional) are included in its composition. Moreover, analysis of cognitive mental structures explicates the problem of mental space, mental time and mental energy, because the spatial organization of mental structures is linked with its dynamic (temporal) span and its energy resources.

Thus, the ontological approach is concentrated on the research into psychic properties of the mental substratum.

The way of implementation of the ontological approach is Differentiation-Integration theory (DI-theory) which is based on two interrelated premises:

1. DI-law of any system development (organic or mental) holds that development involves moving from states/forms of relative globality and undifferentiatedness towards new states/forms of ever-increasing differentiation and hierarchical integration (Werner, 1957; Chuprikova, 2007; Kholodnaya, 2002; Volkova, 2011 etc.).

2. Mental structures underlie human psychological development including the development of intelligence, competence and creativity (Chuprikova, 2007; Kholodnaya, 2002; Volkova, 2011 et al.).

Among mental structures the most important structures are the concepts, which form the highest level in human mental organization. The efficiency of conceptual thinking depends on the organization of conceptual structures. Due to conceptual thinking, individuals are capable of classifying, identifying, generalizing and emphasizing essential attributes of their environment, that is, by using subjective means the human being is able to construct an objective mental “picture” of reality and guided by it in his/her activities. Namely, conceptual thinking, according to K. Popper, ensures a combination of “control and freedom” which determine productive capabilities of human intelligence (Popper, 1979).

L.S. Vygotsky emphasized that conceptual thinking is the highest form of cognitive activity which re-organizes all other cognitive processes. The higher is the level of generalization conceptual structures (that is selection of

different generalized features of certain concepts as well as the links between them), the more pronounced are the effects of conceptual thinking on the various types of cognitive functioning (Vygotsky, 1982).

According to L.M. Vekker, conceptual structures are the “centres of crystallization” that form conceptual systems providing a holistic work of intelligence (Vekker, 1998).

The similar idea was expressed by R. Li that conceptual thinking is the basis of intelligence. According to his theory of conceptual intelligence, the human intelligence is always conceptual intelligence, i.e. intelligence emerges as a result of conceptual thinking (thinking in concepts) and conceptual learning (mastering concepts) (Li, 1996). Another version of interpretation of the nature of conceptual structures and their role in cognitive activity represented in the theory of “mental spaces” by J. Fauconnier (Fauconnier, 1996) and “conceptual blending theory” (Turner, Fauconnier, 1995). Blend mental space, generating in the process of operating the meanings of words, regarded as the basis not only of mastering and operation concepts, but also the emergence of new ideas (including metaphors).

1.2. Conceptual structure and their empirical indicators

A brief literature review shows that the word “concept” has many meanings and is interpreted depending on the context in different ways. For example, in contemporary philosophy, the term is regarded as mental representation or the ability of a “cognizing” agent. According to F. Aquinas, the concept is the inner comprehension of things in mind, expressed through the sign, through the unity of the ideal and the material-phenomenal.

There are notions about the concept as mental formation (“clot” of culture in human consciousness) through which culture enters into the mental world of a person.

Concepts are not only thought of, they are experienced by humans. They are the cause of emotions, sympathies and antipathies, and sometimes of collisions.

From the psychological point of view, we must distinguish the external concept from the internal one.

The external concept is a concentrated expression of historically acquired knowledge about an object or a phenomenon. It is an external for a person knowledge which is to be acquired.

The internal concept is a substratum of the external concept, providing its mastering, operation and change in the individual mental experience of the person. Scheme; a semantic network; generalization; mental space are the closest sub-referential terms. Exactly the availability of internal concepts and operatively forming on its’ basis mental representations of what is happening enables us to explain the seemingly trivial fact that people have different understandings and evaluate the same situation, different release properties of the same object, different interpretations the content of one and the same concept.

The concept has a hierarchical structure that represents levels and vertical interrelations between system elements, where each element is determined by a set of general and specific characteristics. The question is how to evaluate the organization of conceptual structures?

Empirical characteristics of the organization of conceptual structures were found in our previous research. E.V. Volkova showed that a complex choice reaction time can be used as a measure of concept organization (precision, entropy), and the forms of concept organization (the number of levels of generality, energy costs of a person) (Volkova, 2011).

More detailed studies by M.A. Kholodnaya revealed such characteristics of the concept organization as the hierarchy, integrativity, extensiveness, selectivity, intensity (Kholodnaya, 2012).

Hierarchy (categorical structuredness) is understood as a measure of differentiation of semantic features of the concept of varying degrees of generality, as a measure of the selection of specific and generic features of the concept.

Integrativity (cognitive composition variety) is availability in the concept composition of verbal, visual and sensory-emotional modalities presented in mode of mutually translating. It was established that the more is the degree of verbally-semantic features generalization, firstly, the more is actualized differentiated sensory-emotional experience as part of the concept; secondly, the more frequently is activated generalized images-models and images-schema.

Extensiveness (breadth of semantic field of concept) is the amplitude of the semantic field of the concept. The higher is the level of the concept development, the greater is the semantic relations with other concepts' domains, i.e. greater number of actualized verbal associations, the more quantity and complexity of the problems formulated.

Selectivity (controllability) is the measure of involuntary and voluntary regulation of the process of actualization of semantic features (involuntary discovering characteristic and essential features of the concept in the free verbal associations in relation to a given concept, voluntary selection of distinctive and essential features of the concept in the mode of his explanation).

Intensity (potential energy) is a measure of concepts' saturation by sensory-emotional impressions.

Thus, the composition of conceptual structures integrate as “underlying” cognitive structures (code information in terms mutually different psychic modalities, visual schema, semantic networks) and “overlying” metacognitive and intentional structures (mechanisms of involuntary and voluntary control of information processing and emotional and evaluative connotations).

So the concept is a locus of different links the different elements of experience, accumulating personal mental resources.

Our study was aimed to reveal interrelations between the organization of conceptual structures and productivity of different types of cognitive functioning.

2. Research Design

Research Design consisted of two independent parallel studies with different diagnostic complex and research objectives. The goal of Study 1 was to study of the structural organization of everyday concepts “Soil” and “Illness” and their relation to the productivity of cognitive functioning. The goal of Study 2 was to study of the structural organization of scientific concept “Substance” and its relation to the productivity of cognitive functioning.

Hypothesis of the studies: The higher is the level of organization of conceptual structures, the higher is the productivity of cognitive functioning.

2.1. Participants

Participants of the first study were Russians, 138 third-year-students of Psychology Department (Kiev State University and Tomsk State University) aged 19-22 years, 71% female. Participants of the second study were Russians (441 persons), including 294 second-year students (19-20-years old, 64% female) from the Chemistry Department (Ural State University), 74 teenagers aged 14 years (58.4% girls) and 73 teenagers aged 15 years (62.5% girls).

2.2. Methods

A multiple design was used in our research including assessment of concept organization (“Integral Conceptual Structures” technique and GreatChemist test), conceptual abilities (“Conceptual thinking” technique), creativity (“Alternative Uses” J. Guilford task, “Circles” E.P. Torrance technique, and TTCT), Wechsler’s intelligence test (WISC, WIAS)), field dependence/field independence (G. Witkin “Embedded Figure Test”), impulsivity/reflectivity (J. Kagan “Matching Familiar Figures Test”).

Methods of assessment of conceptual structure organization

Study 1. The short version of the “*Integral Conceptual Structures*” technique enabled to explicate three components of concepts (e.g., everyday concepts “Soil” and “Illness”) such as verbal-semantic component (“Problems Formulation” technique), visual component (“Visual Portrait of a Notion” technique) and sensory-emotional component (“Semantic Differential” technique) (Kholodnaya, 2002; 2012). Three standardized z-scores indicators (the complexity of the problems, generalized figurative translation number of selections in the column “weak-medium” of semantic differential) were summarized to get the indicator “level of conceptual structures”.

Study 2. “*GreatChemist*” test is used for estimation of the organization of the scientific concept “substance”. The formulas of chemical compounds appear on the screen in a random order. The participant must divide these stimuli into groups according to the instruction: into two groups (global level), into 4 groups (basic level), into 15 groups

(detailed level). This test allows us to measure the maturity of the concept organization (the choice reaction time (T, sec), quantity of errors (n)) and quantity of levels formed. The level is formed, if the accuracy of responses reached at least 90% (Volkova, 2013).

Methods of assessment of conceptual abilities and special chemical abilities

Study 1. For the assessment of different aspects of conceptual abilities methods “Generalization of three words”, “Free sorting words”, “Conceptual Synthesis” was used.

“Generalization of three words” (Kholodnaya, 2012) tests the conceptual categorial ability – generalizing of the concepts on the ground of their essential characteristics. In each word triad, all the three words belonged to different semantic fields; the general characteristic of the words within the triad was unobvious. Index: the sum of the scores for all 10 triads (voluntary categorial generalization).

“Free sorting words” (Kholodnaya, 2012) tests the conceptual categorial ability – the subject was required to spread 35 cards with words denoting the different aspects of the category of “time” into groups in the most convenient, logical and natural way, from their point of view. Index: the quotient of categorization (the sum of the base points for all selected groups to the number of groups) (involuntary categorial generalization).

“Conceptual Synthesis” (Abraham, Okoniewski, Leman, 1987; Kholodnaya, 2012) tests the ability of making connections between concepts on the basis of three unconnected words; the subject had to construct “impossible” semantic connections as micro text and record multiple responses for each triad of words. Index: the complexity of the connection (the sum of the scores of all the responses to the four triads of words) is used as an indicator of conceptual generative abilities.

Study 2. For the assessment of different aspects of competence (special chemical abilities) method of long-term memory for the chemical information (%), method of “chemical” intuition (0-60 points); map of interests (-10 to +10 points) were used (Volkova, 2011).

Methods of assessment of productivity of cognitive functioning

Study 1. *J. Guilford task “Alternative Uses”* (verbal creativity) indices fluency and originality.

E.P. Torrance technique “Circles” (nonverbal creativity) indices elaboration and originality of completed circle names.

“*Embedded Figure Test*” (EFT, Witkin, Oltman, Raskin, & Karp, 1971) is administered individually and requires detecting a simple embedded figure in a more complex one. The score determines a mean time (sec) of solving problems. The higher is the mean time, the higher is the degree of field dependence.

Matching Familiar Figures Test (Kagan, 1966) identifies the cognitive style of impulsivity/reflectivity (cognitive tempo). This cognitive style describes one of the aspects of the mechanism of involuntary intellectual control, namely the ability to involuntarily slow down a response to gather information when faced with a situation of multiple choice.

Study 2. *Wechsler Adult Intelligence Scale* is used for measuring person’s global capacity to act purposefully, to think rationally, and to deal effectively with environment (Wechsler, 1981). The Russian version of the WAIS (Filimonenko & Timofeev, 1995) consists of 11 subtests: Information, Comprehension, Arithmetic, Similarities, Digit Span, Vocabulary, Coding, Missing details, Block Design, Object Assembly, Picture Completion, Digit Symbol, and Picture Arrangement.

Wechsler Intelligence Scale for Children (WISC; Wechsler, 1991) is used for young people under 16 years old (Russian version WISC by Filimonenko, Timofeev, 2006).

Torrance Test of Creative Thinking (TTCT, Ball & Torrance, 1992) consists of a verbal (verbal creativity) and a figural (nonverbal creativity) test battery. The use of this test permitted us to identify such creativity indicators as fluency, originality, elaboration, resistance to premature closure and abstractness of titles.

Academic achievement was estimated as a mean score on chemistry (0-5 points). 5 points corresponds to an excellent knowledge, 0-2 points corresponds to poor knowledge

Mathematical data processing was carried out by using the ABM SPSS software package 19. Statistical processing techniques of empirical data included descriptive statistics; parametric methods for identifying relationships: factor analysis, regression analysis and dispersion analysis.

3. Results

3.1. The results of the first study

The results of factor analysis of the indicator “level of formation of conceptual structures” and indicators of conceptual (categorical and generative) abilities are shown in Table 1.

Table 1. Factorial matrix of indicators “level of conceptual structures” and conceptual (categorical and generative) abilities (n = 93)

Indicators	Factors	
	1 Factor (38.6%)	2 Factor (37.8%)
The level of conceptual structures, z-assessment	0.181	0.845
Voluntary categorical generalization, points	0.849	0.205
Involuntary categorical generalization, point	0.876	0.136
Complexity of the connection (conceptual synthesis), points	0.153	0.858

According to our data (Table 1) the abilities of voluntary and involuntary categorical generalization form an independent factor (1-st factor) whereas the level of conceptual structures is connected with the ability to the conceptual synthesis (2-nd factor). The data obtained suggest the existence of different types of conceptual abilities: categorical abilities, providing the corresponding object to the assignment of a certain category (categories) based on transformations in the system of categorical signs of varying degrees of generalization and generative abilities, responsible for originating of mental contents, namely the identification of implicit links and laws; the construction of new ideas, including conceptual metaphors; forming interpretations; creating mental narratives. Respectively the question arises how conceptual structures and indicators of verbal and nonverbal creativity are connected.

Factor analysis of indicators “level of formation of conceptual structures”, verbal and nonverbal creativity resulted in the extraction of two factors explaining 74.8% of general variance (Table 2).

Table 2. Factorial matrix of indicators “level of conceptual structures”, verbal and nonverbal indicators of creativity (n = 45)

Indicators	Factors	
	1 Factor (49.5%)	2 Factor (25.3%)
The level of conceptual structures, z-assessment	0.74	0.07
Fluency (verbal creativity), points	0.83	0.20
Originality (verbal creativity), point	0.78	0.45
Elaboration (nonverbal creativity), points	0.79	-0.41
Originality of title (nonverbal creativity), point	0.09	0.92

As can be noted, the indicator “level of conceptual structures” is presented in one factor, along with two indicators of verbal creativity (fluency, originality), and one indicator of nonverbal creativity (elaboration) (1 factor). However, the indicator “originality of title”, that participant of the study give to their finished drawings (nonverbal creativity), forms a separate factor (factor 2). Thus, the higher is the level of conceptual structures, the higher is the probability of generating creative (but not rare!) ideas. We believe that the maximum high rates of originality responses can be observed at a low level of formation of conceptual structures, because emergence of super original ideas is rare in terms of the of frequency of occurrence and absurd from the standpoint of their possible semantic connection with the original object, perhaps a consequence of the reduction of the conceptual control.

Further, we verify whether the level of conceptual structures is connected with the control of processes of information processing. Factor analysis resulted in the extraction of factor which weights included with significant

such indicators as “level of conceptual structures” (0.563), field-independence (short time of finding simple figure in a complex one) (-0.757) and reflectivity (latent time of first answer) (0.700).

That result indicates that the level of formation of conceptual structures is associated with field-independence and reflective (slow) tempo of decision-making, in other words it is a manifestation of involuntary intellectual control as the ability to control of the process of information processing (the influence of the visual field and “to keep a pause” in the decision-making process).

3.2. The results of the second study

The results of the relations between the indicators of organization of concept “substance” and indicators intelligence (WISC, WIAS) in adolescence and early adulthood are presented in Table 3.

Table 3. The values of angular coefficients (α) in the regression equations $T = A - \alpha \cdot IQ$

The levels of organization of the concept “substance”	Group of examinees		
	14-year-olds (n=74)	15-year-olds (n=73)	19-20-year-olds (n=294)
Global level, T1sec	1.38	0.65	0.295
Basic level, T2 sec	2.99	1.7	0.267
Detailed level, T3 sec	The level is not formed	4.14	1.46

The findings of regression analysis showed (table 3), that the higher is the level of organization of the concept “substance”, the higher is the relation with the indicators intelligence. So, the higher is the level of organization of the concept, the higher is the productivity of intellectual functioning. These findings are consistent with the results of the formative experiment presented in previous paper (Volkova, 2013), which reveal that is the purposeful formation of concept “substance” entails the development of intelligence.

The results of dispersion analysis (One ANOVA Test) revealed a significant association between indicators of competence in the field of chemistry and the organization of the concept “substance”:

Factor “Global level” is associated with indicators of encoding of chemical elements ($p_1 = 0.022$); the span of long-term memory for the chemical information ($p = 0.045$); interest in the study of chemistry ($p = 0.003$); experimental skills ($p = 0.034$); common chemical abilities ($p = 0.034$).

Factor “Basic level” is associated with indicators of academic achievement in chemistry ($p=0.032$); coding rate numbers signs of chemical elements ($p_2 = 0.001$); the span of long-term memory for the chemical information ($p = 0.047$), problem solving ($p = 0.05$), interest in the study of chemistry ($p = 0.007$).

Factor “Detailed level” is associated with indicators of academic achievement in chemistry ($p = 0.037$); productivity of memory ($p = 0.007$); chemical intuition ($p = 0.014$).

Of particular interest are the data on the relationship between indicators the organization of the concept “substance” and of creativity. It is necessary to emphasis that detailed level of concept “substance” is formed only in gifted chemists. The findings devoted to the empirical verification of the hypothesis about the relationship between the emergence of new ideas and the formation of a new (detailed) level of cognitive conceptual structure are described in our previous paper (Volkova, 2014). Thus, the highly differentiated conceptual chemical structures cause a creative nature of chemical thinking and allow chemists to find new interesting facts in the substances.

4. Conclusions

We used different concepts (everyday and scientific) and diagnostic tools. Different participants were invited to take part in our studies. They were students of different ages, different departments, from different cities. Nevertheless, we obtained the similar results: the higher is the level of conceptual structures, the higher is the level of conceptual abilities, creativity, involuntary intellectual control, competence and successfulness in real professional activity.

The results of our research allow us to reveal such components of thinking as categorical abilities and conceptual abilities. Categorical abilities provide extraction of feature of varying degrees of generalization and the formation of relationships in the system of specific and generic terms. Conceptual abilities underlie the process of generation of new of mental contents such as implicit signs, contexts, and interpretations.

The degree of maturity of the conceptual structures is first of all related to the same type of conceptual abilities, i.e. conceptual generative abilities. We believe that the level of formation of generative abilities characterizes the individual intellectual resources by providing a decisive influence on the productivity of all kinds of intellectual activities.

The degree of maturity of the conceptual structures is related to verbal and nonverbal creativity. Namely, the higher is the level of conceptual structures, the higher is the probability of generating creative (but not rare!) ideas.

In turn, the higher is the level of conceptual structures, the higher is indices of field independence and reflectivity, that is the higher is the ability to control of the process of information processing (the influence of the visual field and “to keep a pause” in the decision-making process).

Thus, the ontological approach allows us reveal a new aspect of the category of “intelligence”. Intelligence is not only a mechanism of information processing (a set of specific cognitive functions), but above all, the mechanism of generation of information and control of intellectual activity. Namely conceptual thinking, according to K. Popper, ensures a combination of “control and freedom” which determine productive capabilities of human intelligence.

One the most important aspect of ontological status of the conceptual structures should be emphasized. Vekker believed that conceptual structure by virtue of its multi-level organization and transitions thoughts on different levels of generalization must have its energy equivalent, i.e. there are relation between the maturity of conceptual structures and energy costs of a person (Vekker, 1976). Volkova showed that a complex choice reaction time can be used as a measure of entropy and energy costs of a person (Volkova, 2011). Another argument to support the view that conceptual structures have energetic equivalent, are the paradoxical results of study, which showed, that the higher is the success of conceptual transformations, the lower is the indicators of brain activity (in terms of EEG indices) (Kholodnaya et. al., 2013).

Based on results obtained, we believe that the ontological approach to psychological research can make a worthy alternative to the functional approach.

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