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THE METHOD OF SET-THEORETIC DESCRIPTION OF PROCESSES: APPLYING IN THE INTELLECT STUDY

Summary

In the article the authors present interpretations of some theories of intellect with the aid of the method of set-theoretic description of process (S-method of process description), developed by them. There are considered descriptions of intellectual processes which components are: the modus of intellectual operations, the modus of the thought object, other modi. The authors show differences between the S-method description of intellectual processes and chosen theories of intelligence. Application of the method provides a consideration of intelligence as a system of processes through the description, for each step changes, of the initial states of components (Prototypes), their final states (Images) and laws of changes (Functions). Theories of intelligence are built on different theoretical foundations and focus on different aspects of intelligence. But these differences were not significantly affect by the use of S-method. The procedure of S-interpretation in all cases was carried out, it seems to us, is quite simple – we had no need to make adjustments to the method or to carry out special theoretical studies. Given S-interpretations differ from interpreted theories by universal description form. It is shown that the S-interpretations for theories of intelligence give a much larger number of options for intellectual processes description. This, in particular, significantly expands the number of hypotheses that deserve empirical testing. Besides it becomes possible to study the set of unobservable background factors.

Keywords: *process, S-method, modus of intellectual operations, modus of the thought object.*

In [1] we have outlined, in particular, a set-theoretic interpretation of intellectual processes and its main types. In this article we present the application of the S-method for describing the content of a number of known theoretical models of intelligence. In addition we would stress the universality and heuristic prospects of S-method in the various studies of intellectual processes.

Basics in S-description for intellectual processes

Clarifying the definition in [1] we call the *intellectual* such processes which are writable as mappings with the *modi* (plural from lat. *modus*) of intellectual operations and/or objects of thought. A set-theoretic description of the intellectual processes may be presented, in particular, as the space of mappings shortly:

$$\{Int; O; D\} \quad (1),$$

Int –intellectual operations

O – object of thought

D – other, except *I* and *O*, modi

We consider only processes in the psyche, so in the recording (1) replace D to Psy (psychic modus):

$$\{Int; O; Psy\} \quad (2)$$

So the recording of the space of mappings for description the intellectual processes is

$$\{Int; O; Psy\} : \{Int; O; Psy\} \rightarrow \{Int1; O1; Psy1\} \quad (3)$$

Formula (3) will continue to be used as the master record of space of mappings for intellectual processes. If necessary, it will be considered some specific areas of such space and its modi will be specified. One of the principles for describing the intellectual processes with S-method follows a consequence of its general provisions and proclaims that each modus in the space of mappings can take any of the three positions in the processes' recordings: function, prototype and image. The result is a more complete theoretical model of intellectual processes. We show what are psychological consequences which resulting from the use of this principle for each of the three modi of the space (2).

Modus *Int*. Processes described with a subspace of mappings in which in the position of function there is the only modus of intellectual operations are suitable for description of various studied in psychology processes with intellectual operations.

$$Int : \{Int; O; Psy\} \rightarrow \{Int1; O1; Psy1\}$$

In psychological theories of intelligence that we will discuss below, we mean the processes of this kind. If the prototype position takes the only modus of intellectual operations, as a result of such process the components of Int-modus become the components of some or all of the modi of this subspace.

$$\{Int; O; Psy\} : Int \rightarrow \{Int1; O1; Psy1\}$$

This means for example that, initially without being an object of thought in solving the problem, the components of the modus Int and can be part of it: for example, a scientist solving a scientific problem, can come to the understanding that it should revise its method of reasoning (intellectual operations). A record of such processes is next

$$\{Int; O; Psy\} : Int \rightarrow OI$$

Similarly, we can consider the contributions of *Int* components to modus *Psy* (for example, bringing the person into his own value system of new value - to develop intellectual abilities).

$$\{Int; O; Psy\} : Int \rightarrow PsyI$$

Finally, if the modus *Int* takes only the position of the image, in processes described by these mappings there are changes of modus *Int* itself.

$$\{Int; O; Psy\} : \{Int; O; Psy\} \rightarrow IntI$$

The processes described by this space of mappings, in particular, contain processes of intellectual development.

Modus O. At position of function is regarded as a regulator of the intellectual processes

$$O : \{Int; O; Psy\} \rightarrow \{IntI; OI; PsyI\}$$

Psychologically, it can be represented as a metacognitive regulation of intellectual processes (on metacognitive processes see eg [5]). The set of mappings with modus O in the position of prototype are descriptions of its impacts on all components of those intellectual processes:

$$\{Int; O; Psy\} : O \rightarrow \{IntI; OI; PsyI\}$$

At position of image the modus O (or rather, OI) regarded as the result of processes in which it has changed at considered stage. For example, while extend the definition of the problem (see.[4]).

$$\{Int; O; Psy\} : \{Int; O; Psy\} \rightarrow OI$$

Modus Psy. At position of function it means that in the processes described by the set of mappings

$$Psy : \{Int; O; Psy\} \rightarrow \{IntI; OI; PsyI\},$$

the regulators are other, except *Int* and *O*, components of the psyche. These may be, for example, sense-of-life orientations.

As *prototype* Psy-modus can be considered as one of the sources of changes in all other modi, including the object of thought:

$$\{Int; O; Psy\} : Psy \rightarrow \{Int1; O1; Psy1\}$$

As *image* Psy-modus (or rather, Psy1) - is a description of mental component which are altered as a result of influence of all intellectual processes at this stage:

$$\{Int; O; Psy\} : \{Int; O; Psy\} \rightarrow Psy1$$

The study of these processes may include, for example, studies of psychological problems influence of the intellectual development on moral.

Descriptions of intellectual processes, obtained by applying this method to different conceptions of intelligence, contain significant methodological (and hence psychological) differences from those conceptions, it will be further illustrated by the examples of:

- Triarchic theory of intelligence.
- John Guilford's model for intelligence.
- PASS theory.

The triarchic theory of intelligence (R. Sternberg)

The author considered it as an attempt to understand the intelligence on the basis of three sub-theories: *contextual* sub-theory linking intelligence with the external environment; *componential* subtheory linking intelligence and the internal environment; *experiential* sub-theory which describes the experience of belonging to both internal and external environment [7] (later the author used and modified the idea of this approach, see. [8]).

Componential sub-theory and its S-interpretation. The component sub-theory considered mental mechanisms that underlie intellectual activity. A component is defined as an elementary information process, which produces operation with internal representations or symbols. Components are classified by function and by level of generality. According to these criteria are highlighted: meta-components (higher order executive processes used in planning, implementation monitoring and decision-making); runtime components (processes used to solve a problem); components of

knowledge acquisition (the processes used in the acquisition of new information). Let's denote: M – modus of meta-components; A – modus of knowledge acquisition; R – modus of memory retrieval; T – modus of transmission of information ; P –modus of execution.

Relationships between the components are performed in the direct and indirect activation of one component to others, or direct and indirect feedback. Since the components M, A, R, T, P are the processes, each can be presented as mapping, in which a certain conversion of object of thought is recorded. Or it may be a sequences of such processes:

$$M : O \rightarrow O1 \quad A : O1 \rightarrow O2 \quad R : O2 \rightarrow O3 \quad T : O3 \rightarrow O4 \quad P : O4 \rightarrow O5$$

where O – the object of thought.

The recording, covering all stages will be as follows:

$$\{M; A; R; T; P\} : O_{(N-1)} \rightarrow O_N$$

To take account of all theoretically possible processes with dedicated components of intelligence and other mental modi of solving the problem it is necessary to investigate all points of the next space of mappings:

$$\{M; A; R; T; P; Psy; O\}$$

If denote:

$$Int = \{M; A; R; T; P\} ,$$

we can go to the original recording for space of mappings of intellectual processes:

$$\{Int; O; Psy\}$$

Among the possible processes, recorded in previous space of mappings, Sternberg consider only those which are in subspace:

$$Int : \{O; Psy\} \rightarrow O1$$

That is, he examined the two process:

$$Int : O \rightarrow O_1I$$

$$Int : Psy \rightarrow O_2I,$$

$$O1 = \{O_1I; O_2I\}.$$

Contextual subtheory and its S-method interpretation. The three kinds of intellectual processes are discussed in this subtheory: adapting to the environment, the selection of the necessary environment, the shaping of the necessary environment. In other words, as intellectual are considered the three types of problem-solving processes in which adaptation, selection and shaping of the environment are the objects of thought. The S-method interpretation of these processes is a record:

$$Int: \{O; Psy\} \rightarrow \{O1; Psy1\}$$

O– the object of thought in specific task (adaptation, selection or shaping of the environment)

Psy– a variety components of the psyche (ie, knowledge) are preconditions for solving the problem and are altered as a result of the process.

Experiential subtheory and its S-method interpretation. In this subtheory a description of the role of intelligence in human cooperation with the task is presented. In this case we consider two options: (a) a relatively new problem for the individual; (b) there is a transition to an automated solving. While remaining within that categorization, in its interpretation, we consider the following components of the object of thought:

- a problem
- a way to solve the problem;
- automation of ways to solve a certain class of problems.

According to S-method, to interpret processes of solutions for non-standard problems we write the following sequence of mappings where at the first stage there is a change of intellectual operations' modus:

$$Int : \{Int; O; Psy\} \rightarrow \{Int1; O1\}$$

O – a way to solve the problem as the object of thought;

Int1 – modus of intellectual operations which supplemented with a new way of solving the problem. At the second stage there is a solving of non-standard problem:

$$Int1 : \{O1; Psy\} \rightarrow O2$$

O1, O2 –a problem as the object of thought at this stage.

Automation of solutions of a certain class of problems occurs during multiple applications of a new method of solving. The automation may be recorded as a sequence of processes of solving similar problems. At the same time there is a change in the structure of modus *Int*, and that leads to transition of control to a higher level. A general process also may be recorded:

$$Int : O \rightarrow \{Int1; O1\}$$

Int1 – modus in which the desired automation achieved.

O – a problem of automation solutions of a certain type of problem.

As in all previous cases, a more complete description of the processes to solving of new problems can be achieved by the construction of the set of mappings with all previously regarded modi and by a further analysis of all theoretically possible processes described in the space of mappings:

$$\{Int; O; Psy\}$$

Combining of subtheories. In the theory of intelligence Sternberg unites three subtheories in a hierarchical structure. The upper level is triarchic theory, the lower levels occupy sub-theory and its components. We show how in the S-method may be consolidated all subtheories and their components. The following types of problems can be specified from the two sub-theories.

From *contextual* subtheory:

- the problem of adaptation to the environment,
- the problem of selection the necessary environment,
- the problem of shaping of required environment.

From *experiential* subtheory:

- Non-standard problems.
- The problem of solving automation tasks.

In addition, we add one more type – standard problems.

From the *component subtheory* we take the structure of intelligence. According to Sternberg, for all types of problems this structure remains the same. So it suffices to consider the generalized modus of intellectual operations:

$$Int = \{M; A; R; T; P\}$$

To specify processes regarded due to subtheories it is enough to denote particular modi *Int* and *O* (see Table *I*).

Table 1.

		adaptation to the environment	selection the necessary environment	shaping of required environment
		1	2	3
standard problems	1	$Int_{11}; O_{11}$	$Int_{12}; O_{12}$	$Int_{13}; O_{13}$
non-standard problems	2	$Int_{21}; O_{21}$	$Int_{22}; O_{22}$	$Int_{23}; O_{23}$
problem of automation	3	$Int_{31}; O_{31}$	$Int_{32}; O_{32}$	$Int_{33}; O_{33}$

So all «actions of intelligence», discussed by Sternberg, now may be recorded as the following set of mappings:

$$Int_{MN} : \{O_{MN}; Ocu\} \rightarrow O_{MNI}, \quad (4)$$

M, N – indexes from the Table *I*.

Substituting to the recording (2) the modi which indexed as in (4), we obtain the following record for intellectual processes:

$$\{Int_{MN}; O_{MN}; Psy\} : \{Int_{MN}; O_{MN}; Psy\} \rightarrow \{Int_{MNI}; O_{MNI}; PsyI\} \quad (5)$$

So we discussed the S-method usage for triarchic theory of intelligence and showed that our interpretation also may be considered as a modification of that theory. Modification includes, inter alia, a substantial increase of types of intelligent processes which may be analyzed and state possible links between subtheories (as well as between their components).

Guilford's Structure of intellect theory

The main points of theory (see [3]).

- Intelligence components are specified through factor analysis.

- The first classification of intellectual factors is based on the allocation of the main type of process or the operation. That is five groups: cognition, memory, evaluation, convergent and divergent thinking.
- Second classification of intellectual factors specifies the type of material or the content included therein. So marked: visual, auditory, symbolic, semantic, behavioral.
- The third classification refers to the final product of the thinking. This product is presented as: units, classes, relations, systems, transformations, implications.
- Intelligence model is a three-dimensional matrix respectively to the classification. Each cell of the matrix is a description of ability, defined by a combination of kinds of operations, their content and the product of thought.

We note some similarities between Guilford's structure of intelligence and S-method description of processes. In particular, space of mappings used in the S-method may be presented as three-dimensional matrix, as well as at Guilford model. The record in General for the space of mappings of the processes, which Guildford takes into consideration:

$$\{Operations\} : \{Contents\} \rightarrow \{Products\} \quad (6)$$

In this general record we may substitute the designations of the modi by those which correspond to the designations of Guildford's intellectual factors. We arrange the association between modi for S-method and concepts used by Guilford

Int– Operations.

O – Content

OI– Products.

Now the record (6) appears as

$$Int : O \rightarrow OI \quad (7)$$

Since in S-method each modus can be considered in three positions of space of mappings (see comments to records (2),(3)), the components of Guilford's model can be represented at the space with format:

$$\{Operations; Contents; Products\}$$

To account the role of other components of psyche is to be added modus Psy:

$$\{Operations; Contents; Products; Psy\} \quad (8)$$

There is significantly larger points In the space (8) than in space (7). Therefore, there is much more theoretically possible descriptions of processes with Guildford's 'factors'. Increasing the number of possible processes is due to taking into account the following groups of mappings.

a). Processes of alteration of modi with the same name. In particular, the *content* (Guildford's term) of intellectual processes themselves are subject to change, for example in the learning process.

b). The results of the mind-processes are also subject to change. In the structure of the space (8) they are taken into account by adding as prototypes the results of previous mental operations.

c). Intellectual operations are also modified over time (e.g., as a result of age-related changes and training) and, therefore, can be considered as prototypes and images of the mappings.

g). Both the content and results of mental operations we consider as modi with the functional components of metacognitive management thinking processes. For example, they can set limits for the exercise of other mental operations.

Once again, we call attention to the fact that the space of mappings describes *theoretically possible* processes. Some of them are obvious and studied in psychology, other – less obvious, and some – are doubtful. Therefore, we talk about the theoretically possible processes, presented as a mappings of sets. For this reason, we propose to consider the space of mappings as a tool to develop and test hypotheses. Something similar we find in Guildford model: he excludes from the analysis of a group of processes which exist in the model, but for which the factors have not been identified. The main difference between the our interpretation of the structure of intelligence and of Guilford's model is in more universal form and a greater completeness of description. Even without changing the structure and contents of Gilford model can be allocated a large number of theoretically possible processes. Some of them can be considered as a kind of intellectual abilities, others - as essential components of these abilities.

PASS theory

PASS theory ([6]) is based on the works of A. Luria on the functional specialization of the brain structures. According to A. Luria, three functional modules, corresponding to the three brain structures, form the four basic psychological process. The first function module enables the regulation of the excitation of the cerebral cortex and attention; the second encodes information in concurrent and sequential processes; the third - forms strategies of development, usage, self-control and control of cognitive activity. These basic processes are: Planning, Attention, Simultaneous, Successive : hence the name of the PASS theory. The processes Interrelate differently for different problems. Knowledge and people skills are a part of each of the processes.

The *planning* processes used to select and develop plans or strategies required to solve complex problems. For this type of process the authors refer to generation, evaluation and execution of the plan, self-monitoring, and others. *Attention* processes are closely related to the orientation reaction, they allow the body to focus in the right direction, focus on the stimulus, without being distracted by others. *Simultaneous* processes are fundamental importance for the organization of information into a coherent whole. *Successive* processes are involved in the processing of stimuli which arranged in series. Components of PASS theory we present as the following modi of S-space: *P* – Planning; *A* – Attention; *Si* – Simultaneous; *Su* – Successive; *KS* – Knowledge and Skills; S-interpretation of PASS theory we get by detailing the components of space(3).

$$Int = \{P; A; Si; Su\}$$

$$Psy = \{KS; Psy_D\},$$

Psy_D – other (except *KS*, *Int*) psychemodi.

Components *Input* and *Output* in PASS-theory (input and output of the information) will be regarded as objects of thinking. The format of space of mappings after the detailing of modi:

$$\{P; A; Si; Su; KS; Psy_D; O\} \quad (9)$$

The space (9) is the most complete description for the theoretically possible ($7^3=343$) processes with the components of intelligence structure in the PASS model.

We note the specifics of some of possible processes from this space. We note that the authors of PASS theory considered only the processes that are presented in the following *subspace*:

$$Int : \{KS; O\} \rightarrow OI$$

In this space there are only two points, ie two mappings defined:

$$Int : KS \rightarrow O_1I \qquad Int : O \rightarrow O_2I$$

Hence, only two components are considered in an altered object of thought:

$$OI = \{O_1I; O_2I\}$$

If the construction of a theoretical model of the task is to more fully describe the factors of the intellectual actions it is necessary to consider all the mappings, in which the object of thought (O) is the image, namely the following:

$$\{P; A; Si; Su; KS; Psy_D; O\} : \{P; A; Si; Su; KS; Psy_D; O\} \rightarrow OI,$$

$$OI = \{O_1I; O_2I \dots O_7I\}$$

Similarly, another mappings can be analyzed, where there is only one image – any of the modi in the space (9). We believe that, as in other cases, we have managed to show that the S-method is a good tool for the harmonization of a particular theoretical model of intelligence, as well as a substantial enrich its capabilities and provides a more clear framework.

Conclusions

Theories of intelligence, which we have chosen to demonstrate the S-method, are built on different theoretical foundations and focus on different aspects of intelligence. These differences, however, were not significantly affected by the use of S-method. The procedure of S-interpretation in all cases was carried out, it seems to us, is quite simple – we had no need to make adjustments to the method or to carry out special theoretical studies. Given in the article S-interpretations for intellectual processes are different from interpreted theories by universality description form. Application of the method provides a consideration of intelligence as a system of processes through the description, for each step changes, of the initial states of components (Prototypes), their

final states (Images) and laws of changes (Functions). The S-interpretations for theories of intelligence give a much larger number of options for intellectual processes description. That, in particular, significantly expands the number of hypotheses that deserve empirical test, and it becomes possible to consider the set of unobservable background factors.

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