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Activity theory as a basis for the study of work

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Activity theory has been successfully applied in diverse schools of psychology with particularly extensive work in the fields of education, ergonomics, human factors and industrial-organizational psychology. However, existing efforts of translation and formulation in English suffer from certain limitations. These limitations include the blurring between Vygotsky's socio-cultural theory of the development of mind and activity theory, the restriction of activity theory in its entirety to the version offered by Leont'ev, errors in the interpretation of some basic concept and terminology, reliance on studies that use obsolete methods, and failure to consider the Russian work in activity theory in its entirety. This last problem results in the omission of the recent advances in engineering psychology and educational psychology in the former Soviet Union that facilitates the application of activity theory to practical problems. This paper is a description of the evolution of basic theory, concepts and terminology relevant to practitioners—particularly in the field of ergonomics.

1. Introduction

One of the leading Soviet philosophers, G. Shchedrovitsky (1995), divided contemporary epistemology into two contrasting, non-exclusive, approaches. One he called the activity approach; the other, the naturalistic approach. In the naturalistic paradigm, individuals confront various objects of nature that are independent of their activity. In the naturalistic approach, unmediated experience is transformed directly into knowledge about existence of objects and phenomena. On the other hand, according to the activity approach, the meaning of human life—things and events, features of those things and events, relationships among those things and events, etc. takes shape through the process of human activity. The purpose of the existential context and its meaning is revealed through activity.

The activity approach and naturalistic approach are not mutually exclusive. Rather, the two approaches constitute complementary frames of reference. Many important studies in the social sciences and humanities have been limited by reducing all methods to the naturalistic approach. Psychology, which in some ways bridges

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the humanities and the social sciences, has been particularly constrained by naturalism. Human information processing, the dominant paradigm in cognitive psychology, may be seen as an instance of the naturalistic approach. The cognitive approach is typically formulated in terms of artificial mentalistic assumptions removed from the concrete study of the human mind in interconnection with real world through mediated activity. A major shortcoming of the naturalistic approach in general is its failure to appreciate the extent to which our knowledge about the external world is intersubjective in nature (Vygotsky 1978) and mediated by human activity. This does not, of course, denigrate the fundamental data derived from the framework of cognitive psychology. Indeed, activity theory seeks to integrate the activity approach and the diverse naturalistic formulations into a coherent framework. Since, human labour is a fundamental kind of activity. Activity theory is of particular utility, not only for theoretical work, but in applied research and practical interventions, as well.

Activity theory has a long history of development in the former Soviet Union. This theory may be considered as a new paradigm for psychology, which is attracting ever-greater attention from professionals in the West. However, the exciting attempts of translation and formulation into English suffer from certain limitations attributable not only to the problems of translating terminology, but also that the activity theory itself emerged from diverse and conflicting schools of thought. Thus, activity theory cannot be reduced to either Vygotsky's socio-cultural theory of mind or Leont'ev's version of activity theory. Activity theory has only recently been used in ergonomics. Practitioners confront a number of difficulties in the translation and interpretation of different concepts and principles of activity theory. Objects of study get confused with units of analyses or objectives. Actions get confused with tasks. Body organs get confused with tools etc. We can consider Engestrom's (2000) study of children's medical care. He described different actions performed by a junior physician. However, what he describes as actions are really tasks in the framework of activity theory. For example, examination and diagnosis of patients is not an action as was stated by Engestrom, but rather a diagnostic task. This task includes distinct actions, and not only subject-object interaction, but also subject-subject interrelationships, as well. Engestrom, in this example, formulates a physician as the subject and the patient and his father as the object. However, in the rubrics of activity theory the patient and his father are subjects; the object of the physician's activity is the health condition of his patients. Moreover, social interaction is also critically important. Therefore, in the physician's diagnostic tasks the subject-object relationship is transformed into subject-subject relationship, and vice-versa. When a physician evaluates a patient's health, we refer to subject-object aspects of task; when a physician speaks with a patient and his father we refer to that as subject-subject aspects of the task.

Others in the West criticize, from the activity perspective, the concept of 'task'. For example, Nardi (1997) wrote that a task is something automatic, neat, pure, and ignores the variability of human activity. She further argues that the notion of task ignores motivational forces. We respectively disagree with this statement. The concept of task is fundamental in activity theory, and it is the major object of study from the activity point of view (Bedny and Meister 1997, Bedny *et al.* 2000). The task in activity theory is inherently a problem-solving endeavour with an underlying subjective mental representation of the task. We briefly address this

topic in what follows. We also respectfully disagree with some authors' interpretation of the concept of activity and action. For example, Kuutti (1997) defines 'building a house' as an activity and defines 'fixing the roofing' as an action. However, both examples are more properly construed as a part of production process, divided into task sequences in which each task constitutes an activity. Tasks may in turn be divided into actions, which can further be decomposed into psychological operations or into psychological acts etc.

There are two approaches in the study of the activity. One approach is called general theory of activity and the other one systemic-structural theory of activity. These two approaches are closely interconnected. In this paper the basic principles of activity are considered from the point view of these two approaches. The current work wishes to clarify some of the specifics of activity theory in order to facilitate its introduction to and adaptation by more Western readers.

2. Emergence of activity theory

Activity theory is a psychological approach which originates in works of Rubinshtein (1935) and Leont'ev (1947). The work of Vygotsky (1978), Bernshtien (1967) and their associates were also implicated in the evolution of the activity theory. More recently, in the West, an interdisciplinary approach to the study of human sciences dominated by psychological activity theory has been derived from philosophical, psychological and sociological work under the rubric of activity theory (Wertsch 1981, Cole 1999, Engestrom 1999).

The distinction between the notions of 'povedenye' which translates into English as 'behaviour' and 'deyatel'nost' which translates into 'activity' provides a good point of departure for understanding activity theory. The term behaviour (povedenye) connotes the 'responses' or 'reactions' performed by animals as reactive organisms. In this case the term 'behaviour' corresponds closely with the American use of the term 'behaviour' in comparative psychology. In the Soviet Union, application of the term 'povedenye' in human psychology is related to an individual's realization of moral standards and requirements. On the other hand, the term 'deyatel'nos't' or 'activity' refers to the human mobilization around conscious goals in a concrete, external world. Inasmuch as only humans can establish conscious goals, only humans can be the subjects of activity. This emphasis on conscious goals in activity theory implies that that human activity develops less from human biology, than from human history and culture.

The common words 'behaviour' and 'activity' were gradually imported into psychology—and the social sciences in general—through a number of different researchers. In the West, J. B. Watson (1925) pioneered the use of 'behaviour' as a fundamental concept in psychology. In the former Soviet Union, at roughly the same time, Basov (1931), introduced the term activity (deyatel'-nos't) into psychology that formulates the subject's relation to the environment not in terms of discrete triggers of habits, but as ecologically meaningful consciousness of the world of work and culture. This formulation of environment is seen to affect human mental processes not directly, but through human activity.

Basov's formulation has affinities with one of the great psychological thinkers of the 20th Century, Lev Vygotsky (1962, 1978). Vygotsky created a comprehensive

framework for psychology inspired by Marxist philosophy, called the 'social historical' or 'social cultural' development of the human mind. Under this framework, human mental development is treated as a process of acquiring culture that in turn shapes human cognition. The hallmark of this theory of culture is the concept of 'sign'—particularly language as an internal tool.

Contrary to much Western writing, while influential in its development, Vygotsky himself did not use the term 'activity' as a basic concept of psychology. Both Vygotsky and activity theorists were responding to the challenge of developing a psychological theory aligned with Marxist philosophy in the early revolutionary culture.

According to activity theory, the human mind develops from historically contextualized, object-practical activity. This object oriented activity determines the genesis and structure of human psychology (Rubinshtein 1935, 1959, Leont'ev 1947, 1977). In Vygotsky's theory, the sign system is to some extent distinct from the object-practical activity (Yaroshevsky 1985).

Vygotsky's theory of the sociocultural development of the human mind, offers an ontology and history of the human mind. The development of human consciousness was always the major object of Vygotsky's research. The human mind is considered above all from an intersubjective perspective. In activity theory, developmental, genetic principles and social interactions are also important, however, activity theory is not focused only on this question.

Frequent assertions to the contrary by Western scientists notwithstanding (Engestrom 2000), activity theory should not be limited to the cultural-historical paradigm. One of the founders of activity theory, Rubinshtein, never belonged to Vygotsky's school of psychology and many of his views diverged from those of Vygotsky. Other founders such as Anokhin (1962) and Bernshtein (1967), established self-regulation as a theoretical foundation for activity theory. Bernshtein also demonstrated that motor action emerges as a psychological problem because motor actions inherently embody cognitive mechanisms. Based on this, in psychology, motor action emerges as an object of psychological analysis for researching cognitive regulation.

Shchedrovitsky (1995), points out that Vygotsky developed a sociocultural determinism of mind, but not of object-oriented, socially mediated, individual activity. This view, which expresses a general consensus in the former Soviet Union (Petrovsky 1984, Yaroshevsky 1985, Brushlinsky 1987) differs from the Western understanding of identity of sociocultural theory and activity theory (Engestrom 1999). Thus, in the former Soviet Union, sociocultural theory and activity theory share some features, but are not regarded as the same. Vygotsky's work has had fundamental influences on psychology in general. In particular it has been relevant for activity theory insofar as Vygotsky inaugurated the sociocultural theory of development of the human mind, but this is distinct from activity theory (Brushlinsky 1987).

As early as 1922, Rubinshtein (1922/1986) articulated a fundamental theoretical principle of activity theory, 'the unity of consciousness and behaviour' that underpin a general psychology and philosophy. He demonstrated that practical manipulation of real objects in conditions of direct contact provides continuous control for thinking processes regulating this manipulation. Mental processes emerge from these processes. From the end of the 1970s through to the present, the need to meet government imperatives to increase the utility of their work, and to the difficulties

practitioners encounter when they attempt to use psychological data to guide interventions, led to contributions and research in activity theory being performed by engineering psychology, work psychology and educational psychology.

3. General characteristics of activity

This brief introduction enables us to define activity as, a goal directed system, where cognition, behaviour and motivation are integrated and organized by the mechanism of self-regulation toward achieving a conscious goal. Activity determines the specificity of interaction of conscious subjects with external world. During this interaction, human mental processes evolve. From this follows the unity of consciousness and behaviour (Bedny *et al*. 2001). Cognitive mental processes evolved as a result of external activity of subjects mediated by intersubjective relations. Activity is object-oriented, artifact-mediated and socially formed system. During activity, humans create artificial objects that are a necessary pre-condition for the development of internal cognitive processes. The inner mental world of human beings is not naturally given, but mediated by artificial objects produced from human activity (Rubinshtein 1935, Leont'ev 1947). Behaviourism formulates behaviour in terms of stimulus and response reactions; activity theory interprets cognition and external behaviour in terms of actions, the specificity of which is determined by the object and goal of activity. At the same time this theory considers activity as goal-directed and self-regulated system.

A comparison with Piaget is also instructive. In Piaget's groundbreaking work, the interaction of subjects with the external world is similarly fundamental (Piaget 1952). However, Piaget does not address the socio-historical dimensions of this interaction in his studies. Rather, the development of the human mind is treated as the isolated interactions of subjects with surrounding objects. Since activity is culturally and historically shaped even when a subject privately and individually interacts with different objects. Object related activity is embedded in socially determined procedures for the manipulation of objects, which is especially true for artificial objects. People live in a world of stable things grounded in particular schemes of action with discrete meanings and purpose. Their internal activity utilizes an historically developed system of symbols and signs such as words, numbers, icons etc., so that objects are not only confronted physically but are encountered in defining inter-subjective contexts.

Social historical analysis reveals two closely related types of activity; 'object-oriented' and 'subject-oriented'. Object-oriented activity is performed by a subject using tools on a material object. The simplest scheme of activity may be presented below as the following three components:

$$\text{Subject} \rightarrow \text{Tools} \rightarrow \text{Object}$$

Through the use of tools, the object is modified in accordance with the required goal. The content of activity progresses through determinate stages; (1) the setting and acceptance of the goal, (2) the orientation in the situation in accordance with the goal, (3) the formulation of the task, (4) the evaluation of one's ability in comparison with the requirements (i.e., evaluation of the difficulty of the task) and (5) development of strategies, etc. Activity is completed only when subjects evaluate the results in accordance with the established goal and criteria of success (Bedny and Meister 1999).

Subject-oriented activity refers to what is commonly called social interaction (obschenie). Social interaction may be presented as follows:

$$\text{Subjects} \leftarrow \rightarrow \text{Tools} \leftarrow \rightarrow \text{Subject}$$

Social interaction, or subject oriented interactions, involves two or more subjects. Like object-oriented interaction, social interaction begins with a subject's goals, orientation in the situation, etc. However, social interaction entails understanding of partners, predictions of their activity, evaluation of the partner's goal, their abilities, past experience, personal features, possible strategies and actions, in response to one's own, etc. Social interaction is constituted by three sets of phenomena—exchange of information, personal interactions and mutual understanding.

Intersubjective interactions may even be found in subject-object activity. Intersubjective relationships arise from the observation of others even without direct contact with them, or from the use of socially developed, informal instructions etc. The intersubjective features of human individual activity, (i.e., subject-object interactions) may be grounded in the work of renowned Russian philosopher and literary theorist, Bakhtin (1982). His career began at the same time as Vygotsky, but continued through the1970s. He elaborated the interdependence of subject-object and subject-subject relationships. In those cases when we talk about subject-object relationships, subjects incorporate consideration of others through 'inner dialogue'. In this dialogue, self-concept obtains its meaning, as well as the 'image of me by others'. Thus, in the study of object-oriented activity, intersubjective relationships must always be incorporated. Social interactions developed in a surrounding world of objects. Similarly, interactions with various objects arise on the basis of social norms and standards. Thus we can eliminate the presumptive opposition regarding the primacy of either subject-object or subject-subject interrelationship between Vygotsky's sociocultural theory, on the one hand, and object oriented activity theory on the other (Bedny *et al.* 2000).

Any activity has a recursive, loop structure, organized according to the principles of self-regulation in which feedback mechanisms that evaluate performance are decisive (Anokhin 1962, Bernshtein 1967, Bedny and Meister 1997). Subjects not only change their own strategies, based on self-regulation, but also scope their external environment. Through mechanisms of self-regulation, internal activity is formed. Internal activity, which at first was performed with support of external activity, is subsequently executed internally. The gradual transition from external, object-oriented actions to internal mental actions is called internalization. In our work, internalization is treated as an active process of formation of internal actions and operations based on the mechanisms of self-regulation (Bedny 1981). This is a formulation of internalization is significantly different from the widely known ones of Piaget (1952), Leont'ev (1977), or Gal'perin (1969). Internalization is described as creative process, which involves different self-regulated mechanisms. The opposite of the internalization process is the externalization process. Externalization is the transition of internal mental actions into the external plane. The processes of externalization and internalization demonstrate that mental or cognitive activity is tightly interconnected with external object-practical activity and that these two types of activity must be considered in unity (Bedny *et al.* 2001). A more detailed discussion of this process falls outside the scope of this paper.

Analyses and description of activity must account for natural fuzziness and nonlinear dynamics (chaos) in regulation of human activity (Karwowski 1991). Since activity is variable, its performance must be modeled probabilistically, as well as deterministically. This enables the researcher to uncover how an operator's activity corresponds to constraints imposed by the purposes of particular tasks and designs.

4. Activity as multi-dimensional system

Activity is a complex, multi-dimensional system, requiring the use of systemic principles. One can extract from the same activity different structures as independent objects of study, depending upon the purposes of a study. Each of these objects of study can be represented as an independent system. Consequently, we may have different representation of the same activity.

Dividing activity into distinct elements and components, and mutatis mutandi from component to holistic activity, is an important part of the system-structural analysis of activity. Morphological criteria entail representing activity as activity-action-operation. According, to structural-functional criteria, activity may be subsumed under a tri-fold rubric: motive-goal-conditions (Rubinshtein 1959, Leont'ev 1977). Platonov (1982) described such activity elements as goal-motive-methods-results. Shchedrovitsky (1995) expanded this to six major elements of activity: goal-task-initial material-methods and product. Motor actions may be divided into motions and mental actions composed of discrete mental acts. Thus, the general structure of activity adduced by various authors converges forming a basis for our formulation of activity (human) and its major elements: (figure 1)

Activity may be presented as a system that consists of heterogeneous, structural elements, composed of different units that allow for the representation of activity in terms of different models describing the same object of study. The description of

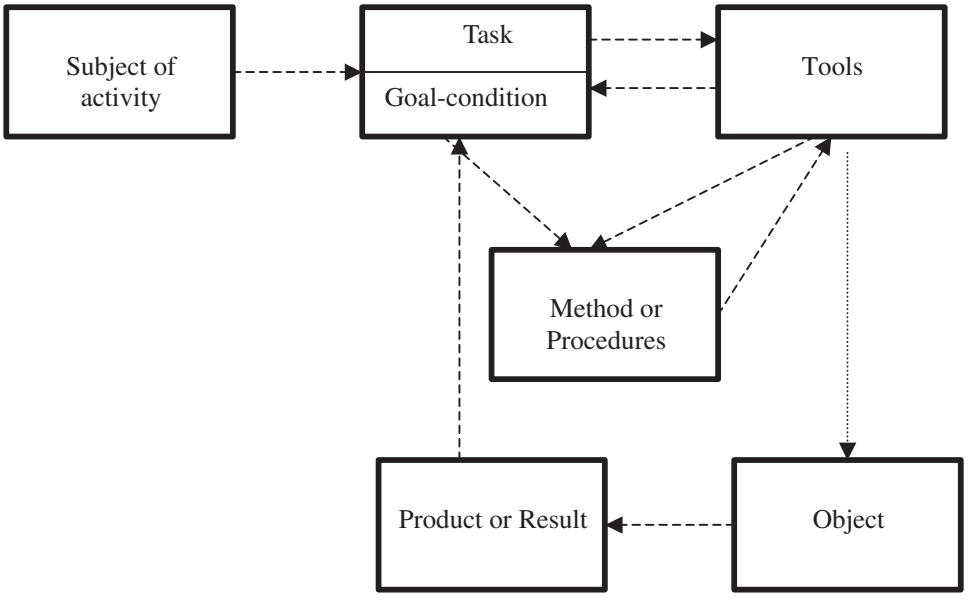

Figure 1. Major elements of activity.

activity as a multi-dimensional system significantly increases the applicability of this approach to the study of human work. We shall briefly consider the subject of work activity and the elements of activity in figure 1.

The subject of an activity is an individual who performs in accordance with conscious goals and tasks embedded in the goals. The subject is an agent with accumulated historical and social experience. Through the objects that they transform, the acting individual emerges as a subject who reflects transformed reality in their consciousness and based on this reflection regulates their activity in relation to others for whom they are a persona (Rubinshtein 1935).

Tasks may be defined as a logically organized system of mental and behavioural actions, directed toward an ultimate task-goal. The task is the basic component of activity and human lives can be conceptualized as an ongoing attempt to solve tasks or problems. Typically, tasks are organized in a logical sequence the performance of which enables attainment of final system objectives. Sometimes such tasks are organized in accordance with technological requirements and are called production operations. Production operations may be studied from a technological frame, or from a behavioural or activity perspective. These two are, of course, interdependent. In the first case, the leading figure is a production engineer or related professional. In the second case, a human factors specialist is called for. However, in certain situations tasks are not well delineated. In accordance with prescribed rules and restrictions, as well as contextual purposes, operators formulate the goal of the task and the task itself. Changes in the situation, conditions or objectives, etc. may lead to reformulation of the task, rejection of the task, shifting attention to new tasks, etc. In some cases, performance of separate tasks entails different subjects requiring coordination of activity among them—including their informal, social interactions.

In order to understand what is a task or an action, it is essential to understand the goal of the activity. A goal is a conscious mental representation of humans' own activity in conjunction with a motive. Goals are cognitive, informational components of activity, that may be contrasted with motives, or motivation in general, which are energetic components of activity. The more intense the motive, the greater the effort to reach the conscious goal. Motive-goals create a vector that lends goal-directed activity its directedness. Methods of task performance are determined not only by the goal, but by conditions in which the goal is presented.

The object of an activity refers to an object that has been modified by the subject according to required goal of activity. This modification includes not only physical transformation, but also, for example, classification of objects according to required goal and existing critiria. Objects also may include elements of the context within which the subject performs of his or her task. People create artificial objects as means of regulating their interactions with the external world and others. These objects are called artifacts, which are seen to hold a central place in the development of the human mind. Not every natural or artificial object is modified by humans in order to achieve a required goal. Subjects can change their own behaviour or activity according to their objective environment. The notion of object of activity is used in order to discern objects that were modified during the achievement of a goal from objects that remain constant, but constrain or affect the performance in activity theory. Specifically, this object is modified and transformed during the subject's performance. Objects that are not transformed but affect a subject's activity can be referred to as task conditions. Objects, which may be either material or ideal, determine the nature of human actions. Ideal objects refer to signs and symbols, and

their constitution as an entity, transformed by the subject in accordance with a required goal. These ideal objects exist in the form of special knowledge about external objects—particularly as images, concept, sign, etc. Depending on the character of the objects transformed, the performed actions can be practical or external and mental or internal.

Another important activity component is product. Product is a result of the transformation of an object of activity. Product may be material, spiritual, or aesthetic etc. Indeed, the subjects themselves may be the objects of change as a result of the activity. This is why, in a theory of activity, instead of the term product one may find the notion of result. Result not always matches the goal of activity.

The next important elements of activity are the tools. They are divided into two types—external or internal tools. With the help of external tools, an individual may transform the initial material or object of activity. Internal tools are internalized or acquired signs and symbols that are used during their internal mental activity. Through the manipulation of signs and symbols, subjects internally transform ideal objects of activity into their requisite product or result.

The preceding elements of activity, methods or procedures include: logically organized system of external behavioural or internal mental actions through which external objects or mental situations are transformed to specification. The method of performance entails a plan of activity within which all components of activity—goals, conditions, tools, etc.—are integrated. The basic elements of activity do not exist in isolation, rather they function as a system.

5. Inducing or motivational components of activity

Interactions among such components as needs, motives, goals, and objects constitute the inducing aspects of activity. Inducing components begin with human needs. Needs are treated as states of individuals which they feel as desire for some objects that are required for survival and growth, that becomes the ground for activity. Human needs are a function of activity itself. Natural things cease to be objects with merely biological meaning. Human needs are the result of acquired experience in conjunction with human culture. Through tool use, humans change objects and modify them in accordance with their needs and goals. During their satisfaction, human needs change and develop. For example, meaning in work and spiritual expression are culturally formed human needs.

Needs become motives for activity when they motivate an individual toward a goal. Motives are defined as the inducing forces that catalyze a person's desire to reach the goal. Satisfaction or non-satisfaction of diverse needs is conveyed by affects and emotions that in turn may induce activity. Such needs become capable of being sublimated into enduring interests, ideals, attitudes and values which in themselves can become motivators. Thus, motives in activity theory include needs, affects, interests, etc., from which activity and goal striving emerge. The same motives under varying conditions can precipitate or influence diverse forms of activity.

Activity can be initiated by complexes of motives with varying weights or priorities assigned to each influencing factor. The relationship among these inducing forces is typically dynamic and subject to modification during activity. Some motives may be salient in consciousness, others may be unconscious. The totality of these motives determines motivation of human activity. Motivation, therefore, encompasses more than the traditional study of motives. As noted, the goal of activity is a conscious future result of an individual's own actions or of activity in general. The relationship

between 'motive-goal' determines the directedness of activity. Motives are the energetic component, while goals are a cognitive element. More generally, activity theory requires that information and energy be treated as distinct, but interrelated factors in accounting for behaviour. In contrast to goals, which are always conscious, motives may be conscious or unconscious. Subjective awareness of the motive may affect the motives involved. The interrelationship among goals and motives is dynamic and complex, and may vary over the course of activity. For example, greater difficulty in attaining a goal generally requires greater motivation for goal achievement.

The specificity of cognitive processes such as perception, memory, thinking etc. involved in task performance to a great extend depend on the vector 'motive-goal', which mobilizes activity into coherent structure. For example, a memorization task is dependent not so much on the nature of the material to be memorized, but on how it is utilized accordance of the goal (Zinchenko 1962). In Zinchenko's experiment, subjects classified cards with pictures and numbers on them. Subjects were instructed to organize the cards either by the picture or by the numbers on the cards. Those instructed to organize by the pictures were unable to recall the numbers. In fact, some insisted that there were no numbers on the cards. Those instructed to organize the cards by their numbers could not recall the pictures. According to activity theory this experiment demonstrates that memorization was dependent not only on the particular features of the stimulus, but also by the way, the material was used. In other words, a memorization task is stipulated by motives, goals, and the method of performing the activity.

Leont'ev (1977) sometimes talks about 'removing the motive to the goal'. However, here we are referring functional coincidence between the motive and goal, and this should not be confused with identifying motives and goals. When motives are 'removed to the goal', the result of activity satisfies goal striving and motivation simultaneously. For example, if a person is very hungry they have a psycho-physiological drive to reduce their hunger, as well as a cognitive representation of the food through which goal they can consummate their hunger. In this case the person's attempts to obtain food for the satisfaction of their hunger, the goals of their activity is obtain the food; the purpose of the motive is also comprised in obtaining the food. According to its functional purpose, the motive and goal coincide. On the other hand, the motivation of a starving person will differ significantly in quality from the motivation of an individual who is not particularly hungry. Often the motives of activity do not, however, coincide with the goal, because the goal may not gratify the motives. For example, a subject may produce something that constitutes the goal of activity but this product may not satisfy a person's hunger. An individual must then exchange the product to satisfy his or her needs. When motives and goals are disparate, the final products or results of an activity are always mediated by the process of exchange. Thus, needs and motives may deviate from goals. This exchange process is unique to humans. Even when goals and motives are functionally matched, we should distinguish cognitive or representational aspects of the goal, from the motivational or energetic aspects.

In activity theory, motivation includes two basic functional mechanisms. One is the evaluative or 'sense formative' mechanism and the other one is the inducing mechanism that is related to 'motives'. The first one embeds within itself cognitive-emotional components based on which the subject evaluates personal significance of performed actions or activity. Sense refers to the emotional colourings an action has

for a subject. The second mechanism (motives) determines directness and energy involved in achieving a specific goal. These two components are intimately interconnected, but sometimes the sense aspect of motivation and inducing aspects of motivation are in conflict. Sense of activity also includes cognitive components. However subjective personal sense should be distinguished from objective meaning. Meaning is a form of presentation of reality to consciousness. Commonly accepted meanings are translated into an idiosyncratic sense for each individual. The interaction of functional mechanisms idiosyncratic sense and 'assessment of difficulty', catalyzes inducing components of motivation. For example, a very difficult task with very low personal significance results in the reduction of the inducing components of motivation. At the same time, very difficult tasks with high significance for subjects result in an increase of the inducing components of motivation. Significance, which derives from personal sense, influences the selection of specific information by an operator, developing strategies and criteria for the evaluation of task performance. From this it follows that the factor of significance introduces the motivational factors into ergonomics research and practice. Motivation can be applied in ergonomics by considering what information and which means of presentation of the information is most important for task performance. This way of dealing with motivation represents a distinctively original approach to motivation in design in ergonomics (Bedny and Meister 1997).

6. Procedural components of activity and units of analysis

During the study of activity we may extract such notions as object of study and subject of study. The object of a study is the phenomenon or object that calls for the use of some theoretical or empirical methods. The subject of study is extracted from the perspective of framing the solving of a problem in terms of a particular aspect of study. Thus we can have a single object of study that should be distinguished from diverse perspectives or subjects of study.

We also distinguish the object of study from units of analysis of activity (Bedny 2000). Units of analysis are unified components into which we divide the whole for the purposes of studying the components and their integration into a dynamic whole. Distinct units of the whole are employed by distinct approaches. For example, behaviourism utilized S-R; gestalt psychology utilized figure-ground; Piaget (1952) utilized operations. Vygotsky (1962) marked out requirements for the units of analysis in psychology. However, he did not himself develop such units. Rubinshtein (1935) and Leont'ev (1947) inaugurated the first general ideas on such units. Among these units the primary ones are internal, mental and external, behavioural actions and operations. The task is a specific kind of activity, which comprises from different actions and operations and presents by itself a complicated system. Accordingly, we consider the task as object study.

Procedural components of activity represent a logically organized system of actions through which an individual transforms activity, or initial material in accordance with required goal. When we study procedural components of activity, the selection of proper units of activity are decisive. Rubinshtein (1959), as Vygotsky (1962), wrote that units of analysis must retain the features of the whole. Analysing into smaller units eclipses the quality of whole. Thus, the primary unit of analysis is action. According to Rubinshtein, actions are basic to both external behaviour and internal mental activity. Actions derive from particular motives and are directed toward a specific goal of action. Motives of each action and overall motivation for

the activity must be distinguished. They may or may not coincide (Platanov 1982). The goal of action should be distinguished from the goal of a task or an activity in general. By performing logically organized sequence of actions, subjects achieve intermediate goals of actions and then goals of task or activity in general. Action is a relatively bounded element of activity that fulfills an intermediate, conscious sub-goal of activity. Rubinshtein and Leont'ev that they were the first to introduce into psychology the concept of mental action, and describe the relationship between motives and goals of activity (Rubinshtein 1935, Leont'ev 1947). The selection of actions as basic units of activity does not compromise the significance of images or meaning in psychology—a perceptual image is the result of perceptual actions of very short duration. Through perceptual actions, subjects develop images of perceived reality. Through thinking actions the perceived phenomena acquire conceptual formulation or meaningfulness. The relationship among images and concepts, or meaning in general, and action is complex. On the one hand, an image is the result of an action. On the other hand, how the image is developed affects the regulation of action.

Vygotsky, who first attended to the units of analysis of mental processes, lacked the time to develop and deploy such units as he adumbrated. In his studies he used meaning as a basic unit. Rubinshtein and Leont'ev argued that meaning and concepts are the result of mental actions or operations, so that meaning cannot be used as a universal fundamental unit of mind. Moreover, the concept of meaning, developed by Vygotsky marginalizes the motivational aspects of thinking processes by emphasizing the cognitive aspects embedded in the his notion of meaning (Gordeeva and Zinchenko 1982). Meaning entails not only thinking, but, other psychological processes. Meaning calls for the integration of diverse psychological processes. Meaning and signs should be treated as psychological tools of mental actions, but not as units of analysis. These meanings are themselves products of action that, in turn, become tools of action in a continuous iterative process. Meaning is embedded within an ongoing loop-structure of activity. Broadly stated, this loop structure of activity consists of discrete actions that include feedback and evaluations of results of performance. This loop structure process for the formation of meaning includes interaction between internal mental and external tool-mediated actions. Cognition is not merely a mental picture of the world. Cognition is also a system of mental actions and operations, intimately related to external actions. Thus, cognitive task analysis used in the field of ergonomics invites blending with activity principles, thereby overcoming the purely mentalistic approach to the study of human performance.

Action may be formulated in terms of the object of action, the tools, the goal of action and the subject of an action. Actions are the result of social-historical development. They are socially mandated prior to subjective realization. Subjects are taught to perform basic socially required actions. Each object has specific associated actions, governed by social norms and values. Actions are facilitated by tools that similarly possess a history and cultural context. Mental and behaviour actions imply the existence of an object of action. They are not isolated, but are typically related to a class of similar actions. Individuals can extract principles of performance of particular actions from these classes because actions from the same class share general functions and purposes.

Between actions and words a similarity exists. Actions possess semantic, syntactic and pragmatic features analogous to words. Syntactic features of actions are determined by their rules of organization into a system. Semantic features of actions

may be discovered through the relationship of an action to its object or to other actions. Pragmatic features of actions can be determined by their role for the subject and particularly in their relation to motivation (Zhuravlev 1981). Verbal activity may also be presented as a system of actions possessing syntactical, semantic and pragmatic features. Verbal actions may be considered as a coherent organization of words around conscious goals integrated into a unified expression (Bedny *et al.* 2000). Verbal actions are more often used as a tool for communication that may also be used as a tool for self-regulation in a dialogic process. Non-verbal actions are typically object actions or may be mental actions involved with the manipulation of mental signs and images.

We also extract a concept of collective action by which we understand actions coordinated in space and time by diverse subjects toward achieving a common goal. In these cases, individual actions of subjects may be formulated as elements of collective actions. Collective actions emerge as a complicated system of individual actions. Practical significance attaches to the study of these systems themselves. Even without direct verbal interaction or direct visual contact with other subjects, powerful social and collective action occurs. As classical economists like to point out in their discussion of abstract market forces, individual actions only require adequate and meaningful information about other subjects engaged in these interactions for coordinated social action to occur.

Typically the names of action and changes performed are formulated as instructions analogous to software code. For example, 'turn on the engine', 'move the lever', 'read display', etc. These kinds of actions are conveyed by instruction, and are classified according to particular specific features of an object. However, actions may also be classified according to their psychological characteristics, i.e., by psychological processes and mechanisms implicated in their performance. For example, 'memorize', 'detect', 'move arm', etc. Based on these criteria we can infer two methods of description of actions. The first consists of actions classified as typical elements of a task, based on technological principals or the nature of modifying the object. The second method is based on psychological principals that involve the description of typical elements of activity (Bedny and Meister 1997). Usually, at the first stage, actions are described according to technological principles and then are transformed into typical elements of activity. For example an action 'move a lever into a particular position' is a technological description of action. At the second stage the same actions may be described as 'move arm into exact position with force of one kilogram and a distance of 30 centimetres'. This last is much more precise. Later, exact descriptions of the actions, unrelated to technological aspects of the situation can be developed. From these descriptions one can infer that this is a motor action that requires a high level attention (third level of complexity) and is performed over a distance of 30 cm with musculature effort which equal one kilogram. This gives us precise picture of motor action even without knowledge of the specifics of equipment and technology is used (Bedny 1987).

In the theory of activity different methods of classification of mental and practical actions are used (Dushkov *et al.* 1986, Bedny 1987, Bedny *et al.* 2000). Actions may be classified in term of their dominant psychological processes—perceptual, decision-making, mnemonic actions etc. Depending upon the nature of the object of actions they may be divided into: (1) object-practical actions performed with material objects, (2) object-mental actions performed mentally with the images of objects, (3) sign-practical actions performed by manipulating external sign and

symbol and (4) sign-mental actions performed mentally through the manipulation of signs and symbols. We can also distinguish external actions in terms of verbal and behavioural actions. Other systems of classification also exist in activity theory. Since action is organized as a self-regulated system, the starting point of any action is the moment when the goal for the action is formulated or accepted. The terminus of an action occurs when the result is evaluated, thereby engendering a continuous flow of activity, divided into individual units, delimited by intermediate and terminal goals subject to the evaluation of the outcomes of the action. Practical methods for identifying types of actions are elaborated by Bedny *et al*. (2000).

There are two types of information processing in cognitive psychology (Schneider and Shiffrin 1977). Controlled processing requires significant conscious effort, increased capacity of working memory, and uses high level concentration of attention. On the other hand automatic processing occurs with little consciousness and requires less mental effort and concentration of attention. Therefore in cognitive psychology a process of skill acquisition and automaticity is explained from the prospective of the information processing capacity of the human brain.

In activity theory cognition is considered not only as a process but also as a structure. Hence activity theory pays a lot of attention to the description of changes in the structure of activity during the skill acquisition and automaticity. According to Leont'ev (1977), actions performed repetitively during training become automatic and unconscious. During training, these actions are then abbreviated and become elements in more complex actions anchored in conscious goals. Leont'ev called these unconscious actions, embedded in more complex ones, operations. Operations that are included in particular actions determine the method for performing actions. The notion of operation in psychological meaning should be distinguished from production operation. Dividing actions into small units is part of the consensual paradigm of activity theory. In the case of motor actions, instead of notions of operations, they consist of motions; in the case of mental actions these may be seen as comprised of psychic acts. Psychic acts can be cognitive actions automated during the training of cognitive action. They lose their quality of consciousness of goal and are thereby assimilated to more complex cognitive actions.

According to Leont'ev, mental and motor operations are always begin consciously; later, during automatization they become unconscious operations. We contend, however, other motor and mental operations exist that are never conscious, but are acquired unconsciously and remain unconscious elements of activity (Bedny 1987). In order for these elements to become conscious, special methods of training and teaching are required. Frequently special training is called for to elevate these operations to consciousness and transform them into consciously regulated actions. Much of the work not only in ergonomics but also in clinical psychology seems to consist of this process.

In activity theory, the study of thinking processes reveals not only conscious thought actions, but also unconscious thought operations. Typically, these unconscious thought-operations, while largely unconscious are critical for catalyzing and mobilizing conscious thought. These unconscious thought operations provide extraction non-verbalized, operational tacit meaning (Tikhomirov 1984). This notions resemble the 'situational concept of thinking' developed by Pushkin (1965). With the help of mental operations that are out of awareness, the subject extracts both conscious and unconscious meanings from the same situation. This continual mental adjustment to the situation in the mind of the subject in light of its

external constancy was called a 'gnostic dynamic'. Thus, not all mental operations are harnessed to the conscious goal. Through these operations, subjects advance and evaluate unconscious hypotheses. These operations are important components of intuitive thinking that develop in close intimacy with object practical activity that is sometimes essentially gnostic.

What we call the morphological analysis of activity involves determining temporal-spatial and logical organization of actions. Morphological extraction of action enables the functional analysis of action. Actions are considered as self-regulative systems. At this stage of analysis the notion of function blocks are also used as units of analysis (Bedny and Meister 1997, Bedny *at al*. 2000). During functional analysis of separate actions they are decomposed into more detailed units of analysis. These units of analysis are called functional micro-blocks. In the micro-structural analysis of cognitive actions, function blocks consist of information processing stages (Zinchenko 1972). Each function block performs a particular function that may be identified through both qualitative and chronometrical analysis of action. Function blocks typically possess a very short duration.

We can also describe activity as self-regulative system. It is functional analysis of activity. During the functional analysis of activity in general (macro-level of analysis), function-blocks have much more complex structure and longer duration. Chronometrical methods here are less important. At this stage specialists describe a process of self-regulation at a macro-level. Function blocks then assume the role of functional mechanisms in the structure of activity that with a particular purpose and with specific interconnections with other functional mechanisms (Bedny *et al*. 2000). The model of self-regulation of activity is comprised of different functional blocks, such as the model of self-regulation of activity developed by Bedny (Bedny and Meister 1997). In this model, the goal is considered as a function block because it not only describes a goal as a functional mechanism in activity, but also delineates the dynamic and integrative causal relationships with other function blocks.

There are different levels of the regulation of activity that are a function of the extent to which an activity is voluntary and conscious. The more complicated levels of self-regulation of activity call for orientation to the situation, development of goals, deliberate planning etc. Highly automated activity entails goals involuntarily triggered by stimuli, which, in turn, guide subsequent cognitive operations and actions. Planning and the evaluation of results are extremely abridged. The lowest levels of regulation guide reactive behaviour. In some cases activity can start from unconscious, automatic operations that can be raised to consciously performed actions at subsequent stages. This process was elucidated in the study of activity of pilots during emergencies (Ponomarenko 1998).

As a result of self-regulation, the same task may be performed in various ways. In response to external conditions and the internal state of the operator, goal directedness, anticipation, and planning combine with flexible reconstruction of strategies of activity. Activity becomes adaptive to the situation. Self-regulation includes conscious and unconscious levels (Bedny and Karwowski 2003b). The first level, derived from voluntarily regulated actions provides conscious, goal directed transformation of information. The second level consists of automatically performed operations regulated by the Set. The Set is an internal state of the organism which is close to the concept of goal but is not sufficiently conscious or completely unconscious (Uznadze 1966).

While, in cognitive psychology, cognitive processes are fundamental, in activity theory cognitive actions assumes occupy this conceptual role. This challenges the understanding of cognition as a continuous, uninterrupted process and adduces object oriented cognitive activity as a discontinuous, interrupted activity. We contend that cognition, when treated as a process, is continuous, but at the same time, is organized into a recursive, loop structure of discontinuous, discrete units that transform from one into another. As light is both wave and particle in modern physics, activity theory treats cognition as a process and as a recursive system of actions or other functional units of processing (Bedny *at al*. 2000).

Delineation of the basic components of activity and units of analysis empowers the design of human-machine systems informed by the alignment and coordination of external and internal means and conditions of activity. External means of activity includes components of equipment and external tools with which a subject interacts during the process of work. External tools of activity refer to presentational controls, displays, screens, instructions, diagrams and other media for conveying information to an operator. Internal tools of activity are conceptual models, images of the external world, skills, knowledge etc. used by an operator during activity. These interactions must, of course, be responsive to external conditions and constraints. Effective alignment of external and internal tools of activity allows for transformation of object of work into required product or result with maximum psychological and physiological efficiency. Individuals in this frame are not construed as a reactive organism, but as a subject whose actions are guided by voluntary, established goals. Therefore, the human-machine interface, or human-computer interaction is treated as an interaction of the subject, tools and objects.

7. Application example

Design is one of the most important issues in ergonomic science and its application. Design can be defined as the creation and description of ideal models of a new object for purpose of their materialization in future. Hence the heart of the design is the analytic methods. However in psychology design reduced to physical modeling of equipment and further experimental studies. These procedures can be used only as supplementary methods of study. Usually in engineering design they are used at the final stage of design. Systemic-structural approach with its carefully developed units of analysis presents a possibility to facilitate psychological aspects of design in ergonomics theoretically or by combining theoretical and experimental procedures. Systemic-structural analysis of activity includes four stages: qualitative stage, algorithmic description, analysis of time structure and quantitative analysis major aspect of which is evaluation of task complexity. All stages have loop structure organization. This means that later stage of analysis some times requires reconsideration of preliminary stages.

As an example of this approach we present very short description of the design of an underwater-unmanned vehicle (UUV). This is a complex robot system. Considering this example presents theoretical and practical interest. In this study, we have compared the analytical description of three design versions of equipment and related models of activity. These three versions are: (1) stable control panel and computer display; (2) rotated control panel and stable computer display and (3) rotated control panel and oppositely rotated computer display. In all three cases it was suggested that the control panel that is positioned horizontally be located on the surface of the vessel or on the shore, in order to control the movement of underwater

robot. The second and third versions of equipment had the inclining and reclining of the panel based on the feedback from the UUV. In the third version rotation on the control panel should be followed by rotation on the display that indicates the position of the UUV, with the same angle but in the opposite direction. The display screen has a scale mask and an icon (a marker) showing the current position of the UUV.

The comparison of the developed analytical models of UUV manipulation demonstrated the advantage of the third version of equipment. The structure of activity described by different models in this case turned out to be simpler, the time of performance was shorter, and the complexity of task performance was reduced. For example for the first and second versions of UUV performance of motor action 'displacement of hand towards the left or right button' (for turning UUV to the right or left) required a high level of concentration of attention. This is caused by the operator having contradictory information when he is moving hand to the right or left button. According to developed procedures of complexity evaluation these motor actions fall under the third level of complexity. In the third version of the UUV these actions always have a complexity level of one, because this contradiction is eliminated and concentration of attention is reduced. In the first and the second design versions the operator must remember the position of the UUV's axis in relation to his/her own body axis during the performance of particular manipulations. Measure of complexity associated with 'proportion of time for retaining current information in working memory' was 0.83. In the third version of design this measure of complexity goes to zero. There were other standardized, analytical measures of complexity not mentioned here that indicate the advantageousness of the third version of design. Thus, the specific design problem of the teleoperation was solved using the theoretical rather than experimental methods. In this complex example practical solution includes the comparison of (theoretical) models of activity with the models of equipment (drawings). We can not describe this study in more details in this work. It is a subject for a separate article.

The same approach was used in design of manufacturing operations, in aviation, training etc (Bedny and Meister 1997, Bedny and Karwowski 2001). This approach was also adapted to the design of computer based tasks (Bedny and Karwowski 2003a).

8. Conclusion

Consciousness, goal-directedness, object-orientation, and tool mediation comprise the distinguishing features of human activity. Other important features of activity include the interdependency and mutual influence of internal mental and external motor activity. This constitutes the unity of cognition and behaviour. From this it follows that cognition and behaviour must be approached holistically. Finally, activity is socially and historically mediated.

Any activity may be treated as a process of obtaining particular product or result that corresponds to the requirements of a task and the goals of an activity. Since during activity performance, we can observe continuous discrepancy between the results and the goals of an activity, the mechanisms of self-regulation of activity are crucial. Results are a function of the specific activity, and the nature of the object being transformed and dynamical conditions under which our activity is performed. Consequently, strategies of activity and our knowledge of the external world are incrementally and iteratively reconstructed. Through activity a person simulta-

neously, transforms or creates the external world, while obtaining knowledge about that world, which, in turn, through reflection catalyzes change in the subject.

Activity emerges as a multi-dimensional system suggesting the use of a systemic-structural approach to its study. Human activity is therefore envisioned as a set of elements or other higher-order components. These elements and components are represented as an organized system. The purpose of a study determines the methods for representing the system. Different models of activity are compared with one another, enabling scientists to infer relevant specifics regarding the activity in question. The systemic-structural method of study in activity theory provides an efficient transition from qualitative procedures to quantitative and vice-versa. Such concepts as culture, goal, significance, motivation, human personality, social interaction, etc. assume importance in the study of work. Activity theory emphasizes that designed technology will be utilized in a particular social context. Here we refer not to the design of isolated technological objects, but to the design of complex socio-technical systems. All of this emphasizes the importance of systemic-structural methods for the study of activity as multi-dimensional phenomena.

Activity theory not only empowers more efficient utilization of existing methods but also developed different practical methods for the study of human performance. Activity theory implies a unified system of concepts, categories and notions. They exist in relationships of coordination, subordination, etc., the most significant of which are: mental and behavioural actions, goal, motive, consciousness, self-regulation, subject, etc. Some categories have a general character; others are more specific. This system of psychological categories and notions are in continuous evolution. However, any changes in a category or notions of activity theory depend on the logic of development of scientific data and reflect a system of objective psychological phenomena. In this regard, activity theory offers advantages over other psychological theories. Since, activity theory possesses rigorous sets of categories, notions, apparatus and well-defined units of analysis of activity this theory is easier to integrate with human information processing. All this has fundamental implications for developing a unified psychological theory for the study of human work.

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