Theoretical Issues in Ergonomics Science
Vol. 6, No. 5, September 2005, 359–383

Man–technology interaction: some of the Russian approaches

VALERY N. NOSULENKO*†‡, VLADIMIR A. BARABANSHIKOV†,
ANDREI V. BRUSHLINSKY† and PIERRE RABARDEL§

†Institute of Psychology of Russian Academy of Sciences, Russia
‡MSH Foundation, France
§University Paris-VIII, France

The purpose of this article is to analyse original Russian studies in the field of man technology interaction in connection with the psychological theory of activity developed by Rubinstein and Leontiev. The main part of the article focuses on the studies carried out in the framework of Lomov's anthropocentric approach and is based on a concept of the mental image as a regulator of human activity. In this connection, several examples are given of psychological empirical studies run in the field of aviation and the main components of a mental image of a flight are considered: a spatial position mental image, a feeling of an airplane and an instrumental model's mental image.

Keywords: IHM; Activity theories; Mental image; Anthropocentric design

1. Introduction

In Russia, sciences studying a man–technology interaction passed a complex way of development, defined to a large extent by an original theoretical basis of the national psychological science. Specific features of the Russian engineering psychology, work psychology and ergonomics (see, for example, Nosulenko and Rabardel 1997, 1998) are related to a wide use in those domains of the concept of activity which are considered in Russian psychology to be a kernel of the 'Man–technology' problem, but are not represented in the West in all their variants and applications.

This paper will show how the Russian perspective on the activity theory in task-oriented settings can help clarify the complex issues that take place in the field of 'Man–technology' interaction. In this connection, it will, first, discuss some aspects of the psychological theory of activity proposed by the Russian psychologist and philosopher Sergej Rubinstein (1889–1960), who is considered to be a founder of the so called 'subject-oriented' theory of activity (see Brushlinsky 1997).

Then, this paper will trace the implementation of some of Rubinstein's ideas in the works of Boris Lomov (1927–1989) who played an important role in the development of Russian engineering psychology, of the psychological anthropocentric approach to the studies of 'man–technology' interaction and of the principles of systems approach to psychological processes.

One will try to present several original Russian studies in the field of 'Man–technology' interaction, a great number of which were based on Lomov's

*Corresponding author. Email: Valery.Nosulenko@univ-paris8.fr

Theoretical Issues in Ergonomics Science
ISSN 1463–922X print/ISSN 1464–536X online
http://www.tandf.co.uk/journals
DOI: 10.1080/14639220500070051

anthropocentric approach in the framework of which a man is considered not as a simple element of 'human–technology' system, but as a core organizing its functioning towards an achievement of the goals previously set.

Several examples are also given of psychological empirical studies run in the field of aviation. They were carried out by Zavalova, Lomov and Ponomarenko and concerned an investigation of the mental image as a regulator of human activity. In this connection, one will consider in more detail such concepts as the 'mental image of a flight' and the 'feeling of an airplane', as well as presenting examples concerning the regulation of a pilot's activity in relation to the condition of an airplanes' automated control. One will compare the situations of manual flying procedures' use with the situations where controlled or completely automated directions were carried out and will show the role of the 'mental image of a flight' in a reliability of the 'pilot–airplane' system.

2. Some ideas on psychological conceptions of activity

The activity paradigm was widely used in the former USSR by representatives of different psychological schools and orientations (e.g. Bassov 1975, Leontiev 1975, Galperin 1983, 1998, Davydov 1996) as well as in some other countries in the fields of psychology, sociology, philosophy, pedagogy and so on (Touraine 1984, Sztompka 1993, Rabardel 1995, Cole 1996).

One of the most systematic developers of the Russian psychological theory of activity was S. Rubinstein, who proposed a conception of the so called 'subject-oriented activity' described in his article 'Principle of Creative Activity' (1922, reed. Rubinstein 1997). In this article (published in English in 1989), the following main characteristics of the subject and his activity were presented.

- *Activity is always done by a human subject* (rather than by an animal or a machine) and, more precisely, by subjects fulfilling a joint activity; an activity can never be done without the participation of a human subject.
- *Activity is an interaction* between a subject and an object; it is necessarily object-oriented and has a specific content.
- *Activity is always creative.*
- *Activity is always independent*; it's independence is revealed in joint activity.

The meaning attributed by Rubinstein to the concept of activity is close to the one represented by the term 'Tatigkeit' developed, first, in German classical philosophy and, then, in the early writings of Marx.

Yet, in 1922, Rubinstein mentioned that a subject not only reveals and manifests himself in his creative acts but it is namely by these acts that he creates himself (Rubinstein 1997, p. 438). He argued that the most important factor for human development was initially practical activity (playing, studying, working, etc), closely related to communication. He stressed that a child's practical actions, rather than the use of verbal signs, represents a genetically initial form of thinking.

In Rubinstein's terms, practical action is one of the most important components of the practical activity. 'Directly related to objective reality, penetrating inside of it and transforming it, a practical action is an extremely powerful tool for formation of thinking, reflecting objective reality; action seems to carry out thinking on its pointed edge, piercing objective reality' (Rubinstein 1935, p. 337). The concept of a primary form of thinking proposed by Rubinstein in 1935 was later confirmed in a number of experimental studies (see, for example, Zaporojets 1960, Galperin 1983, 1998).

Rubinstein argued that all forms of thinking keep their connection with practice. The character of this connection is different: 'it is mediated in theoretical thinking and direct in practical thinking. Theoretical thinking, based on practice, does not depend on a single particular case of practice; while practical thinking is always directly related to a particular situation, in which an action is realized' (Rubinstein 1935, p. 333).

As for the structure of activity, as was created by Rubinstein in the 1930s and 1940s, its main components are represented by motives, goals, actions and operations (ways of realization of actions). According to Rubinstein, integrity of activity manifests itself mainly in the integrity of a subject's goals and its inducing motives. Activity-related motives and goals, unlike action-related motives and goals, usually have an integral nature, express a personality's general orientation and, thus, are called initial motives and final goals. On different stages of activity, the activity-related motives and goals generate different specific motives and goals, which characterize the actions. Since an action, being a kind of a means, brings up a result (brings the person to the realization of their goals in different sets of conditions), it becomes the decision for a task (that is a more or less complex intellectual act).

Rubinstein's conception of activity structure is somewhat different from the one proposed by Leontiev in the mid-1940s (Leontiev 1975). Leontiev, while considering the same activity components, strictly refers motives to the whole activity, goals to actions and operations to concrete situations. In addition, Leontiev interprets the motive not as a kind of experienced need but as a material or ideal object of need.

The peculiarities of Rubinstein's approach to the problem of activity and reflection are connected with his understanding of the relation between internal and external as reflected in his interpretation of the determinism principle (Rubinstein 1957). Any influence is considered to be an interaction, in which the effect of external reason is more or less modified by internal conditions; internal, in any case, mediates external. Internal conditions are all those hereditary and genetic deposits, psychological characteristics, life experience and, generally speaking, the whole personality of an individual, that already exist in the moment of a new exterior influence.

The way Rubinstein interpreted the determinism principle was connected also with the meaning he attributed to the concept of reflection. According to Rubinstein, the mental images of a reality belong to a subject being a real practical actor. It is the subject, who carries the modus of activity and plays the role of integrator, unifying the different psychic phenomena and levels of organization. Reflecting a reality, a man orientates in it and expresses himself as integrity.

Rubinstein introduced a new plan of analysis of psyche, considering it as a process. His ideas about environment and concrete life circumstances as the main sources of the diversity of psychic phenomena are very important for the practical studies of human–environment interaction. In fact, all of Rubinstein's theoretical ideas concerning activity (the principle of creative activity developed in the 1920s, the principle of the integrity of consciousness and activity—in the 1930–1940s, the determinism principle—in the 1950s) concerned primarily man's practical relations with his environment.

When considering the ways the Rubinstein ideas correspond to the studies of man–environment interaction, an analysis of some of Lomov's works is worthy of interest. His name is connected with the development of engineering psychology in Russia and, more broadly, with the development of the problem of human factors in complex 'man–technology' systems.

Not without Rubinstein's influence, Lomov analysed activity in a social and historical plan. According to Lomov, activity should be analysed both at an individual and social level of human existence; its subjective plan rather than its content or structure is the point of interest. The subjective plan of activity includes forms, types, levels and dynamics of individual psychic reflection. Namely, in activity the psyche reveals itself as a system and the activity itself forms one of the main determinants of psychic phenomena.

Lomov's ideas on the psychological structure of individual activity were developed on the basis of research on a skilled operator's work in engineering settings (Lomov 1963, 1977, Lomov and Surkov 1980, Zavalova *et al*. 1986). They proved that individual activity was a component of the joint activity of people. Thus, Lomov argued that understanding individual activity in its totality means defining its place in joint activity as well as defining the individual's function in the group. According to Lomov, research on joint activity introduces an innovative approach to the analysis of activity units, structure, levels of organization and development (Lomov 1978, 1979, 1981, 1984, Lomov *et al*. 1985).

The research on joint activity was realized by Lomov together with the psychological analysis of communication. Lomov showed that, like activity, communication determines psychic phenomena. It defines development of cognitive, emotional and motivational processes as well as the formation of personality and interiorization of social and historical experience. Psyche, in its turn, regulates the process of communication and its development. Communication as a category introduces into psychology a unique aspect of human existence, which incorporates a particular class of characteristics, functions and laws of psychic reflection of reality.

Lomov's solution for the problem of the psyche-activity relationship was based on the concept of the integrity of external and internal factors developed by Rubinstein (1946, 1957). Thus, according to Lomov, the psyche could not be considered as an interiorized activity, equal in structure to an external activity. The study of the structure and dynamics of psychic processes, involved in activity, rather than the reduction of the external to the internal (or vice versa) was considered to be the goal of psychological investigation.

As for the development of some of Rubinstein's other ideas in the works of Lomov, the common view of both scientists on the concept of reflection should be mentioned (Barabanschikov 2000). Lomov concretized this view in experimental studies of perception, representations and anticipation. Using the systems approach, Lomov formulated the basis of systems conception of psychic reflection (Lomov 1984).

As for the impact of Lomov's works on the development of the 'human–technology' systems research, his anthropocentric approach to the study of those systems should be mentioned.

3. Anthropocentric approach

The anthropocentric approach was considered to be a general line of development for engineering psychology in the former USSR. Within this approach, different lines for the analysis of 'Man–technology' systems corresponding to different aspects of human activity can be distinguished. An extensive analysis of practical studies in the framework of the anthropocentric approach is represented by Golikov and Kostin (1996).

The term 'anthropocentric approach' was proposed by Lomov (1975) in order to characterize the method of analysis of the relationship between people and technical systems. However, the initial outline of this approach had been presented for the first time in 1963, in the paper entitled 'Man and Technology' (Leontiev and Lomov 1963).

This approach was opposed to the technocentric approach to the 'Man–technology' system. The later was based, according to Lomov, on the principle of simplification that reduces the importance of human activity.

The anthropocentric approach means that a man is considered not as a simple element of a 'Man–technology' system, but as a core organizing its functioning towards an achievement of the goals previously set. Therefore, consequently, the 'designing of an operator's activity' means simultaneous realization of the two lines of research: a technical system's conception, on the one hand, and an analysis of human activity within this system, including education and training aspects, on the other hand.

The anthropocentric approach considers the man–technology relationship as the one between '*the working subject*' and '*the work tools*'. In fact, in the framework of this approach, the human goal-directed activity is the basic systems process and it is the man who becomes the core of the system's functioning towards realization of the goals. Being the fundamental element of this system, a man organizes its functioning, and directs it towards a concrete result, fixed beforehand by him. Man provides a flexibility of the system's functioning. He determines tasks, executes actions as well as evaluating the results. Thus, the technical systems cannot be considered to have the same importance as the man because they are the tools, the means used by man to realize his actions and to obtain information on these actions. The analysis in terms of 'inputs' and 'outputs' is not sufficient for the analysis of a man: it is the psychological study of the human activity structure and its mechanisms that should be the principal point of investigation.

Since the anthropocentric approach was developed within the framework of the psychological theory of activity, it concerns the analysis of an operator's activity structure and dynamics, as well as a study of the mechanisms of its psychic regulation. This approach considers man as the subject of work, cognition and communication. So, it is argued that the goal of the engineering psychology is *the designing of the human operator's activity* (Lomov 1975, 1977).

The designing of the operator's activity is not reduced to a list of actions and regulations. The main element of such a design is a description of the psychological constituents of human activity in the technical system. Such a description should anticipate the different variants of realization of actions and should evaluate the way the proposed interfaces ensure an anticipation of the system's functioning by an operator. The activity design also aims at the analysis of an operator's actions in the framework of an automation of the 'Man–machine' system: both actions to be automated (developed to the level of skills), and actions for which automation is dangerous, should be identified.

The particular importance of the design is to define the 'zones' of activity which need 'creative decisions'. In such a design, the formation in man of activity's planning skills, of self-control skills as well as skills for the use of personal reserves in order to create the special behaviour mechanisms in unpredictable situations (incidents) are supposed to be carried out. The conception of technical tools (interfaces, control and communication systems, etc.) is incorporated in the working out of the operator's activity psychological design. Technical means are the only means of a human conscious and goal-directed activity. The psychological designing of the activity becomes the basis for integrating all tasks related to the conception of a 'Man–technology' system.

The anthropocentric approach is the common referential framework for different lines of analysis of human activity in technical systems. A practical example of its application is the principle of '*an active operator*' (Zavalova *et al.* 1971, 1986). This principle proved to be most effective in the field of aviation.

For example, according to the active operator principle, the level of man's readiness for action defines the efficiency and reliability of the functioning of the 'human–technology' system. That is, at any time, he should have the possibility not only to observe, but also to influence the states of objects being under his control. This principle explains the high level of efficiency for the mixed (automatic + manual) control of an airplane. Therefore, the reduction of activity (of the possibility to fulfil the actions directly) becomes a reason both for different sorts of serious mistakes and for the operator's refusal to continue to work in situations of partial technical failure. This is also valid for failures, which can be resolved by the 'active operator'. Thus arises the need for the maintenance of an operator's active condition as well as of his readiness to solve motor, perceptual and cognitive problems in exceptional situations. The automation level should guarantee a constant control of the operation process according to the information provided by automatic machines. At the same time, some control is to be executed by the operator himself.

4. Lomov's concept of the vector 'motive–goal' in human activity

According to Lomov, the concepts of motives and goals are crucial for the psychological analysis of activity. Motives and goals form a sort of activity 'vector', defining activity's direction as well as a subject's efforts necessary for its execution (Lomov 1977, 1984). This vector is the systems-forming factor, the pivot of the psychic processes' system and states, which are formed and unfold in the course of activity. This vector must be considered in connection with both activity results and its object and conditions. The dynamics of the processes of perception, memory, and thinking, as well as their inter-relations, depend to a great extent on this fundamental component 'motive–goal'. This vector determines perception selectivity, attention characteristics, and the operative extraction of different kinds of information from memory and their use in reasoning. It also determines the dynamics of psychic states. In the same way, the 'motive–goal' vector defines the dynamics and intensity of emotional states.

A motive refers to the need inducing an activity, while a goal refers to the object, at which an activity is directed. The activity goal is an ideal representation of the future result of the activity and it defines the nature and ways of one's individual actions. Thus, a goal is a phenomenon of an anticipatory reflection. The goal is set under the influence of social regulations, norms, laws, etc., but it cannot be reduced to them in any way. Lomov emphasizes that a goal is not imported into an activity, but is set by the individual himself. Rather, a requirement to an individual other than a goal could be set from outside. Thus, the formation of goals is a deeply personal process; the study of this process has to take into account individual social development, i.e. a history of the development of a person.

Lomov argues that the activity's complexity will depend upon the 'discrepancy' of a goal from an object, that is, the 'discrepancy' between the available object and the expected result, as well as from the available means and the individual level of their acquisition. Any psychic process includes an element of anticipation, i.e. the expectation of current events; it reflects not only the object's actual condition, but also the tendency of its change. The results of anticipation form the basis for the process of goal setting.

According to Lomov, the study of a goal setting plan of psychic processes puts forward the question about the form in which the goal manifests itself for the subject. A goal may be represented as a perceptual image, as a mental image-representation or as a particular 'logical construct' (a system of judgements and deductions). The form of manifestation of a goal depends upon the concrete conditions in which the subject is going to act as well as from his psychological characteristics. When a goal is considered to manifest itself as a perceptual image (for instance, in a visual tracing), this does not mean that it is connected only with perception. Its formation is impossible without the participation of thinking, subjective representation and memory. That is, all levels of psychic reflection do participate in the setting of a goal and, depending on conditions, some of them become leading. In this sense, a goal is a system of integrating structures, a specific form of anticipatory reflection.

Thus, according to Lomov, the 'motive–goal' vector is the highest activity regulator, which defines the structure and dynamics of all other components. In the process of personality development each new goal, which is set and realized, brings about changes in one's motivation sphere, which, in its turn, creates the possibility of new goals setting. This position was analysed in detail by Lomov in his studies of man and his technological environment interaction.

As far as activity is oriented to the future, i.e. to something that does not yet exist, mental image plays an important role in activity regulation. The question is a man's conscious anticipation of a system's condition, which must be reached as a result of the work with technical tools. At first, this anticipation emerges as a mental image formed by an operator, namely the 'image–goal' (Lomov 1977).

5. Image–goal

An object is reflected in a subjective representation of a goal (in Russian it translates literally as 'image–goal') not as constantly changing by itself, but as a result of activity. The concept of the 'image–goal' demonstrates a relationship between the mental image and the result, for the sake of which an activity is undertaken and stresses the important role of a subject's conscious personal attitude to a task. The setting of the goal is a process, characterized by a specific relationship between the subjective sense of a task and its objective importance. The goal is not imported from the outside, but is set by an individual himself (Lomov 1984). Technical tools used for the presentation of information greatly influence the dynamics of an operator's image–goal formation. Actually, the operator's choice of information as well as its interpretation and use depend on the nature of a mental image and the future state of the system being directed.

According to Konopkin (1980), the goal adopted by a subject is the most important and the leading component of the conscious regulation process. The goal's regulative function is defined as system-forming. Due to this function, the whole process of self-regulation forms a 'vector' with a given direction. The goal acts as a conscious determinant of information selection that is the necessary condition for a real goal-oriented regulation of an activity.

An 'image–goal' reflects an object as changing as a result of activity (Lomov 1984). An 'image–goal' seems to 'absorb' ones past professional experience and includes a representation of activity tools, i.e. it is mediated by technology used in the process of activity. It determines the selection, integration and evaluation of information as well as hypothesizing formation and decision-making. 'Image–goal' must be conserved during the whole period of activity, otherwise activity becomes disorganized, a phenomenon that sometimes occurs in situations of increased stress. The inclusion of a goal into the formation of a mental image determines the main function of the latter, that is a directed regulation of an action.

An 'image–goal' formation is closely related to the prognosis and anticipation of changes of object, environment and operator's states. However, in order to control a system it is not enough to anticipate its future condition. Some information on the current system's condition is also needed. That is why Lomov (1977) emphasizes the following points.

- First, in the process of an activity all sensory organs of a man function as a unified system, ensuring the reflection not only of the operated object, but also of the environment and the organism's states. As a result of this integration, a mental image is formed, which reflects an object as well as the conditions and tools of the activity. It is impossible to analyse the information on object's states independently from all other influences on the human sensory system. It is particularly important, in each concrete situation, to reveal a relationship between the information received from devices ('instrumental information') and the one that is not processed by devices ('non-instrumental information'). For example, in critical situations the 'non-instrumental information' can dominate and determine human behaviour.
- Secondly, a human operator usually does not have the opportunity to directly observe an operated object: his perception is mediated by technical systems and the information received is often encoded. In these conditions, an operator constructs a certain '*conceptual model*' (Welford 1961). The concept of the 'conceptual model' is close to the concept of an '*operative image*' proposed by Oshanin (1966, 1973).

'Conceptual model' and 'operative image' are the fundamental concepts widely used in Russian psychology for activity analysis in human–technology systems.

The concept of '*conceptual model*' was proposed by Welford (1961), who interpreted it as a global mental image constructed by an individual. He considered that, although such a model is often rough and imprecise, it gives an operator a holistic picture and ensures a possibility to relate different components of an integral process and to act effectively. At that time, Welford's idea was considered revolutionary for the Anglo-Saxon engineering psychology, where the most widely-spread schemes and concepts were borrowed from technical sciences and interpreted an operator's activity in terms of 'input' and 'output' characteristics, 'transmission functions', etc. In Russian engineering psychology based on the reflection theory, the importance of the simultaneous analysis of external forms of activity and internal subjective processes has always been emphasized. So it was logical to quickly assimilate the term 'conceptual model' in order to interpret psychic processes.

The works of Gordeeva *et al*. (1975) are examples of the specific usage of this term in Russian approaches. Conceptual model is considered as an essential internal means of activity (from Lomov's point of view the term should be a component of psychological structure) emerging in the process of learning and training. The conceptual model incorporates a man's experience of life, his knowledge acquired by professional training and information collected by a man when he is exerting control over the object. The model's content includes mental images of real and anticipated situations of the activity as well as the knowledge of possible executive actions and characteristics of an operated object. The model also embraces a general representation of system's tasks, the activity motivation and some knowledge of the consequences of accurate and fault decisions. It incorporates a certain readiness to unexpected events as well. Conceptual model is an operator's inner world. It is based on a great amount of pre-conceived information received from an environment. It forms a relatively constant background for human actions as well as a basis for decision-making. It is characterized by its information redundancy; in a concrete situation, an operator actualizes and brings in to consciousness only the related-to-object content of a mental image necessary for solving a concrete task. In this work, the conceptual model is interpreted as the global, complex and dynamic related-to-object mental image. What is more, the conceptual model reflects the innate dynamics of an object and a nominal structure of the process (i.e. the structure as it should be represented in an operator). The content of this constant conceptual model is relatively independent from the actual conditions and circumstances of the object-related action. In this sense, the content is abstracted from actual conditions and exists prior to the beginning of concrete actions. Conceptual model is the basic structural component of object-related reflection. It is its global mental image.

Understanding of the conceptual model is an important element of psychological analysis of an operator's activity. Furthermore, some other questions come to mind. For example, how does this model develop in the process of activity and how are the actions regulated?

In order to clarify these issues, Oshanin (1966, 1973) proposed the concept of *operative image*. Unlike a pre-formed conceptual model, an operative model is the specific mental image of an object, generated during execution of a concrete action. An operative image may also be regarded as a mental image of immediate action in reference to the task, or as an object-related image or purely effectoring image of an object (engramme). When speaking about an operative image that regulates activity, its dynamic, variable and contradictory nature is emphasized. At the same time, special attention is attributed to the mechanisms of concrete actions' regulation by a comparison of correlative and correlating mental images and anticipation of current processes in mental images. Operative images are connected to certain stages of activity.

While the main characteristic of the conceptual model is its relatively constant content, the operative image is characterized by its dynamics. It is the dynamics of a mental image, in particular, that ensures efficiency of its regulating functions. This is a general characteristic of human reflection of reality.

According to Konopkin (1980), the most important feature of the process of actions' regulation (self-regulation) is its dependency on the content of the goal as it is understood and adopted by a subject. This means that it is impossible to define the content of an image–goal only on the basis of analysis of objectively given conditions of an activity (e.g. tasks, information models, space and time constraints, sets of technical tools of activity, etc.). It is also necessary to reveal subjective conditions of activity: motives and personal attitude to a task, determined by a number of such factors as the value of activity results for a person, the extent to which the task is difficult for him, the level of his general and special training, his internal readiness to act at a given time, content and quality of received information, etc.

Therefore, it is necessary to take into account two levels of the process of analysis of information concerning the operated object. The first level is related to the perception of those physical phenomena that carry information usually transmitted from indicators and control devices. On the second level, the mental image, formed on the basis of this information, is transformed into a conceptual model (Lomov 1977).

In practice, the task to transform the object of control from one state into another is considered by a subject as the task to minimize a discrepancy between a conceptual model (which characterizes the actual state of the object) and the image–goal (in which the expected future state is represented). The level of the task's difficulty is defined by the magnitude of this discrepancy. The bigger the discrepancy the subjectively more difficult is the problem for a person. The level of difficulty depends on the degree of development of both the image–goal and the conceptual model.

The concept of a mental image is crucial for psychological analysis of activity and a lot of research concerning its relationship with activity was carried out in Russian psychology. As for the empirical studies concerning the role of a mental image in the system of psychic regulation of activity, investigations conducted by Zavalova *et al.* (1971, 1986) in the field of aviation are of a special interest.

6. Mental image in the system of psychic regulation of activity

A 'mental image of a flight' is the most general concept used in aviation psychology in order to designate psychic regulation of man's actions in flight, i.e. in specific environmental conditions. In fact, a mental image of a flight is a system of psychic regulation of a pilot's actions.

In order to reveal the specificity of this mental image, characteristics of the informational environment of a flight are taken into account (Zavalova *et al.* 1986). This environment includes two types of signals: the *instrumental* ones that are received from devices and the *non-instrumental* ones that occur as a result of man's direct actions, i.e. as a result of the transformation of an operated object's state (airplane evolution, changes in the schedule of the aggregates' work, etc.). Due to these specific features of the informational environment of a flight, a pilot acts both as an automated system's operator who uses, to control an airplane, an informational (instrumental) model and as a person who directly perceives and feels information about an operated object's changes. All actions carried out with a controlled object are reflected both on *indicators* and directly in *perception* (e.g. as changes in a pilot's body position). As far as instrumental and non-instrumental signals could be contradictory in some situations, the operative image being under formation should permit a pilot to solve these contradictions. The image incorporates knowledge on flight control as a whole along with some purely pragmatic components regulating operative actions. The holistic knowledge is regarded as a redundant one from the point of view of a 'pure control of the flight', and is gradually and consciously acquired in a pilot's professional experience. This characteristic of an operative image has great potential because it is formed on the basis of the mental image of a flight, being a stage of realization of the latter in a concrete flight situation.

According to Zavalova *et al*. (1971, 1986), the so-called mental image of a flight in aviation can be compared with a conceptual model. The mental image of a flight includes the pilot's tasks and goals, a system of knowledge about an operated object, and a system of motor programmes realized in flight. During concrete actions and depending on flight conditions and pilots' goals, one of the following three components of a mental image of a flight comes to the forefront: a *spatial position's mental image*, the *feeling of an airplane* or an *instrumental model's mental image* (perception of information represented on the airplane devices).

The *spatial position's mental image* regulates the pilot's spatial orientation, i.e. his knowledge about an airplane position in relation to earth. A pilot, who is subject to acceleration forces going in different directions, must constantly process information in order to orient in space. This means that during the flight a pilot must receive and process information having as goals both the control of an airplane and the orientation in space. The spatial position's mental image must be constantly maintained and transformed in accordance with an airplane's evolution and in opposition to the destructive influence of non-instrumental signals, if they give information contradictory to the instrumental one. Ensuring a pilot's general orientation, which includes a comprehension of the flight's global goal, the spatial position's mental image plays an auxiliary role in the direct regulation of operative actions. The regulative function is carried out by the instrumental model's mental image.

The *instrumental model*'s mental image, also called 'instrumental image' or 'fork image' (Frantsen *et al*. 1967), is a reflection of discrepancy between prescribed and current modes of flight. This discrepancy is formed on the basis of information on the divergence between some prescribed value of the flight's parameter and the actual position of the index. The dominance of this component of the mental image of a flight at some stages of piloting brings about an automation of operative actions—a phenomenon, which becomes evident in the long and undisturbed horizontal flight of a heavy plane. In other situations, the 'instrumental image' predominates if there is a necessity to urgently redirect a plane from a complex (incomprehensible) position to a horizontal flight (adjusting to a horizon). In the latter case, the automation of actions can be a reason for crashes: an absence of a conscious mental image of a spatial position (e.g. knowledge on flight altitude) can be dangerous if automation is carried out at insufficient altitude. The fact that the instrumental mental image is laconic and not redundant often causes its functional deformation: only the one signal from the group comes in the forefront and, thus, the rapidity and accuracy of one of the action's components is ensured, while the potential reliability of the action as a whole is reduced.

The third component of the mental image of a flight, namely *the feeling of an airplane*, has a specific content. This content is related to receiving the non-instrumental signals: acceleration, vibrations, resistance of control apparatus, noises, etc. These signals play a complex and a contradictory role. First, they are referred to as negative flight factors, representing physical influences unpleasant and dangerous for an organism. Secondly, they can be incorrectly interpreted by a pilot and, in consequence, can serve as a reason for wrong decisions. However, they are very important for a pilot's sensation of fusion with an airplane, since this sensation facilitates an anticipation of changes in the position of the latter, ensures economy of motions, as well as creating a generally positive emotional background for a pilot's activity.

A feeling of an airplane is the fusion of a man with an airplane giving a possibility to physically feel the airplane movements. It facilitates one's ability to adequately and accurately perceive and unconsciously select all sensory stimuli important for the control of an airplane, as well as helping to successfully react to those stimuli by the movements of an apparatus of control. Here is the definition of the role of the feeling of an airplane, given by an aviation psychologist Heratevole (1956, p. 183):

> The co-ordination of movements necessary for a control of an airplane is realized not only consciously, but also by means of the sensory relationship with the machine and by the adjustment of a flight to its natural mode. This 'natural mode' could be a real and live aesthetic experience for emotional people, which in consequence could transform a flight into an emotional experience and even a passion.

Speaking about the feeling of an airplane, it is important to indicate its relationship to a pilot's actions. An action of control changes an airplane position, but at the same time a pilot receives both instrumental and non-instrumental signals. A pilot evaluates all these signals both as changes in the controlled object and as a result of his own actions, more precisely, as changes in the controlled object being the results of his own actions. An airplane is considered to be *an instrument of activity*, a *continuation of the organs of the human body* (Lomov 1977, 1984).

The content of the third component of the mental image of a flight is constantly changing. A personal experience in the interpretation and evaluation of arising vague sensations is necessary for its formation. These sensations must gradually become more distinct in the course of activity in order to regulate the pilot's actions. Herewith, the feeling of an airplane ensures the performance of movements, directed to anticipate those deviations, that are not yet visualized on the devices. These movements are the pilot's reactions 'in a flash'. They eliminate a dangerous situation before it becomes irreversible and before it is reflected on an informational model. The feeling of an airplane cannot give a representation of accurate changes in flight parameters and cannot be a single regulator of operative actions. However, it is supposed to direct the pilot's attention to the control of those flight parameters, which need prioritized actions.

Zavalova *et al*. (1986) emphasized the dynamic and constantly changing structure of the mental image of a flight. The three components of the mental image of a flight constitute complex and sometimes contradictory inter-relations. The sensory-perceptive content is characteristic to a spatial position's mental image and to a feeling of an airplane, while the motor regulation is carried out on the basis both of the feeling of an airplane and of an instrumental image (fork image). Predominance of the devices' mental image being a regulator of motor actions facilitates the actions' automation and, in consequence, the fixation of the mental image's functional deformation. The latter can be interpreted as a reduction in the reliability of a 'plane–pilot' system.

A number of studies were devoted to the analysis of specific features of the pilots' flight images (Zavalova and Ponomarenko 1980, 1984, Zavalova *et al*. 1986). In these studies, interviews, questionnaires, free descriptions, etc. were used as methods. Results indicated that, as a rule, the content and functions of the mental image that regulate actions in flight are rather clearly represented in the conscious mind of experienced pilots. For instance, the specific feature of the 'instrumental mental image', namely the regulation of operative actions in complex situations requiring urgent control intervention, is well represented in a pilots' conscious. In ordinary circumstances, a regulation of an activity by means of the 'instrumental mental image' is automatic and it is not necessary to have this component in consciousness.

It is well known that pilots are against the reduction of piloting in deference to the formalized action of 'arrows collecting', as well as of the reduction of a flight image to its instrumental analogue. The instrumental component of the mental image of a flight could be built only on the basis of a holistic mental image. Tzuvarev (1977), for instance, defines the following main characteristics of the 'mental image of a flight' and its 'instrumental analogue':

- The mental image of a flight is primarily a general concrete visual representation of the flying machine's position in space, with a prevalence of the qualitative side over the quantitative one. Its instrumental analogue is a narrower, abstract and formalized representation of certain components of the mental image of a flight, with a prevalence of the quantitative side over the qualitative one.
- A mental image of a flight is logically formed or created according to the needs and on the basis of a pilot's experience of life, his knowledge and various informational sources, including the instrumental analogue. Pilots, even inexperienced ones, logically and without any effort form a correct mental image of a flight, especially in visual flights with small and average heights and good visibility of landmarks. In other situations, the formation of this mental image needs some effort, which depends on flight conditions, on a pilot's professional experience as well as on quality and amount of information received. An instrumental analogue is created only on the basis of the information within a cockpit as well as on the basis of the reinforced by practice relationship of this information with the real mental image of a flight. When this relationship is strong enough, an instrumental image can appear involuntary. In fact, this is nothing else but the automatic skills used in control of an airplane.
- In order to control an airplane on the basis of the mental image of a flight, the conscious actions are needed, i.e. a thinking pilot. On the other hand, in order to do piloting on the basis of the instrumental analogue of the mental image of a flight, that is to combine arrows and indexes in the required direction, it is not necessary to have a pilot in the control's circuit. The automatic pilot can fulfil this task more successfully by means of using its specific program (Tzuvarev 1977, p. 13).

An instrumental image can be destroyed as well. This is a situation pilots term 'scattered arrows'. It characterizes the period of a flight when a pilot loses his ability to act effectively because he cannot understand indications shown on the devices and does not know either what to do or what position the airplane is in. At the same time, he has no illusory feelings about the airplane's position that contradict with indications on the devices. In fact, it is the flight's instrumental analogue that has been lost or destroyed. During the flight outside of the visibility zone this means a certain impossibility to maintain the representation of one's spatial position.

According to the results of studies carried out by Zavalova *et al*. (1986), pilots understand that motor skills are sometimes sufficient for the control of an airplane as they allow an 'arrows' co-ordination' without referring to a holistic representation of the flight. However, it should be emphasized that this type of control is not considered to be crucial for a flight. Moreover, such a flight is not a flight: 'you are forgetting that you are flying'. Automation, 'formalization' of actions, is related to the fact that during the control of an airplane, in a certain moment, the 'zeroing of arrows' becomes the goal. Pilots are opposed to this process, the 'maintaining of flight's mode' and contest the opinion that the mental image of a flight can be replaced by its instrumental analogue. Instrumental analogue exists, but it is impossible to reduce the mental image of a flight to it.

Zavalova *et al*. have shown that, during a flight, there is a constant comparison of the image–representation (the referent operative image), based on the memory of a perceptional image in a visual flight and the perceptional image of a set of indicators on the devices. The perceptional image can support the visual image-representation formed earlier and also gradually change its content. However, pilots cannot create by themselves the perceptional pilots' image without the support of a memorized visual image. For example, pilots indicate that, despite the fact that horizon and earth are represented as moving in their visual sensations, they learn to see (the precise term is see) them as immobile. Experienced pilots do not make any special effort in order to conserve a correct mental image of space during visual flights.

According to Zavalova *et al*. (1986), during the flights, the pilots are unable to see the horizon as an immobile one, when the avia-horizon's indicator shows it as a moving line. So, if pilots have not thought about the principle of spatial position's indication on the glass panel indicator during visual flights, they immediately notice a revolving horizon line in the indicator during ordinary flights. This fact disturbs their spatial orientation, i.e. their adequate mental image of a flight. The revolving horizon line shown on the indicator imitates every horizon motion caused by changes in visual afferentation and in this way contradicts the accurate mental image of space used by a pilot to direct an airplane command. The use of such indicators requires special transformations of perceived information as well as additional mental efforts.

So, one can conclude that a pilot not only fully understands and imagines that the earth is stationary and that an airplane is moving, but also learns gradually, with experience, to see (to directly perceive) the earth as stationary and an airplane (and himself together with it) as moving with reference to terrestrial co-ordinates. So, there is kind of a restoration of 'vertical gravity', 'top' and 'bottom' and of all other spatial reference marks in their initial situation. As it could be supposed, this means that a new functional organ of spatial orientation has been formed in a pilot, thanks to which the imaginary vertical becomes comparable to the real one.

Here, an analogy with objects' perception through tools is possible. A tool (or instrumental) sense of touch serves as an example. It is well known that during the touch of an object by a stick (or a probe) the investigated object is localized on the tip of this stick: as if sensitivity was transferred there. This is possible because this instrument is included into the hand's co-ordinate system, as if it becomes one of its organic components (see Ananiev 1959, 1980). In the same way, due to the feeling of an airplane, the movement of an airplane participates in the movements of a pilot (or vice versa).

The analysis of available material leads to the conclusion that the verbal (verbal-logical, conceptual) level of reflection has a fundamental organizing role in the formation of the mental image of a flight. Sensory data, being incorporated in a mental image, is in any case interpreted and analysed in accordance with an activity's goal.

The level of representations also has an essential place. These representations primarily exist in a visual form. Visualization is a necessary constituent of the mental images' formation process. The representations incorporated in a mental image are characterized by a high level of clarity, vividness and broadness.

The role of non-instrumental signals is contradictory: their advantage is the maintenance and strengthening of the mental image's regulative function and their disadvantage is the weakening of its cognitive function. The mental image of a flight has a spatial and temporary character as far as its object-related content refers to a moving object; that is why this mental image is rather dynamic: at any time a current mode of flight is compared to the prescribed one. Thus, the complete mental image of a flight must be anticipating, i.e. its realization must comprise the anticipation process. That is why it is organically related to the perception of time.

7. Peculiarities of mental image as determined by automation of the process of control

An automation of operations brings about changes in the human role in the process of control. In some cases, it dispenses with the operator's information collection, selection, processing and storage; these operations are given to technical tools, while a man has to make decisions and to perform control actions. In other cases, on the contrary, a man is supposed to collect and process information, to make decisions, while technical tools perform executive functions. Yet, in other cases the whole control process is done by technical tools (automatons) and a man is supposed to survey their work and to intervene, if necessary. Changes in human functions logically lead to changes in the structure and psychic regulation of human activity. Thus, automation of control systems does not reduce the role of sensory and perceptional processes and puts forward a number of new problems to cognitive psychology (Ananiev 1960, 1968).

In automatic control systems, human actions are regulated by perceptional (generally, visual) images. However, this process of formation of a mental image has some essential features. Mental image is not formed by the direct perception of real objects, but on the basis of the perception of the object's informational model, coding the information in form of signs. That is why one of the crucial elements in an operator's activity is the process of transformation (re-coding) of sign information into visual image. As noted by Krylov (1972, p. 73), visualization is the 'optimal form of internal organization of input information'. This means that the mental image that regulates human actions in an automated control system is still a perceptional image which needs for formation a conscious transformation of signals by means of thinking.

As was shown by Gordeeva *et al.* (1975), a mental image can become perceptually empty for a man, operating the object by means of its informational model.

This, in consequence, could generate a degradation of man's capabilities of evaluation of reality and of one's responsibility for the executed task. Otherwise, there is a specific relationship between intellectual and perceptional processes, which becomes evident during work with informational models. The above-mentioned specificity poses the task to accumulate the sensory and perceptional elements in the mental image and to regulate the operator's actions. The solution to this task is of great importance for an increase in the operator's activity and responsibility during his interaction not with a real object, but with its information model.

The first part of the study carried out by Zavalova *et al.* (1986) was related to a situation of a directed control. In this type of control, an operator has the executive functions. It is the operator who moves the organs of control, executing commands that are transmitted from the onboard computer. Commands are given via directive signals; they indicate to a pilot the direction and amplitude of movements of the organ of control. In this case, the collection of pilot signals (perception is semi-automated), their analysis and making of the decision about ways of action's performance is automated (more precisely, semi-automated). Unlike the directive mode, in the automatic mode, the pilot is deflected from physical influence upon control organs (executive operations are fulfilled by an automaton).

In both cases, the piloting, as a pilot's main activity, is simplified. Simplification consists of the reduction of the level of psychic regulation, so that premises are created for the conversion of a goal-directed action with a high degree of conscious control into a 'mechanically' executed operation. Herewith, the pilot's main goal, namely the flight's successful execution and termination, does not change.

The system of piloting devices gives a pilot the information necessary for both forming a general representation of an airplane's position in space and piloting in order to maintain an airplane on the prescribed itinerary. With the establishment of directive indicators, the pilot got new command signals, which are complementary to the old ones and very suitable for regulation of the executive acts. This improvement of the system's indication has changed the perception of piloting information: it has simplified the operative content of actions. At the same time, the content of the mental image that regulates activity also changed. Authors put forward the hypothesis that the mental image of a flight is reduced when the directive mode of control takes place. This hypothesis was tested in experimental flights, where trouble in the work of directive indicators was modelled.

The results of these experiments showed that it was not only the perception itinerary that changed, but also the object-related mental image content, which was actually narrowed and semantically poorer. Instead of the fully developed mental image of a flight, a pilot was guided by one of its components, namely the instrumental image. This means that, in the directive mode of control, the level of actions' regulation is diminished: the latter is done on the level of direct perception of elementary sensory characteristics of abstract symbols. The image–goal being formed is reduced to a representation of the required position of the indexes' cross-point in the centre of a device and the piloting actions were reduced to the 'zeroing' in of a signal. Thus, the structure of the mental image of a flight changes. All cognitive components, which reflect an airplane's position both in space and on its itinerary, are excluded from this structure. This puts limitations on the pilot's activity.

According to Zavalova *et al.* (1986), the mental image reduction is determined by the following circumstances.

First, the directive mode of control objectively requires that the pilot concentrates his attention on directive indexes; therefore, an accuracy of piloting is closely connected to the exact and constant visual tracing of them. At the same time, the presence of command signals is the only factor determining the type of operations with control's instruments. There is some evidence for this supposition based on the data received in real flights. In the directive mode of control, the pilot, even after passing over clouds, i.e. in a visual flight at a height of 100 m, continues to concentrate his attention mainly on the control of command instruments (during 65% of the flight time his glance is fixed on these instruments). This means that, even when there is a possibility to use natural information (e.g. observation of a terrain), the piloting stays at the level of a blind flight and is generally reduced to a visual tracing of the directive indexes.

When using the non-directive piloting devices, the final result of the control could be reached in different ways; in this case, both the result and the method of control considerably depend on the pilot's individual characteristics. In the directive mode, the pilot's individual characteristics are of no importance. A high level of accuracy of the instrumental piloting in difficult weather conditions is reached due to the sub-ordination of the pilot's movements of control to the commands of the board computer.

Secondly, during the directive control, the pragmatic sense of the spatial position mental image is lost. The instrumental mental image is sufficient for all immediate piloting goals during the whole flight. Usually, pilots need practical knowledge on the airplane's spatial position: this knowledge often defines the choice of the method of control, including the sequence of the devices' control. In the directive mode, the most complex and creative element of action, namely the construction of a flight dynamic image, containing knowledge on the global flight mode and on the actual position of an airplane in space, loses its significance for piloting. The fully developed mental image of a flight, regulating the piloting process during the manual control, loses its pragmatic regulative function. In the directive mode, the pilot can easily maintain the flight itinerary without having to consciously consider the airplane's spatial position. The generalized directive signals he concentrates on don't give any information about the airplane's position; they only inform about what should be done in order to put an airplane in a certain position. In the directive mode, the immediate practical result of actions does not depend on the pilot's fully developed object-related mental image of a flight. The mental image of a flight necessary for piloting according to devices loses its pragmatic function. This leads to a reduction of the subjective value of evaluation of readings of information devices and to a change in action's goal: the goal to maintain the flight itinerary is replaced by the goal of zeroing in on directive indexes.

In the directive mode, the signal seems to give the ready solution concerning an airplane movement. This signal increases the efficiency of the 'Man–airplane' system but, at the same time, reduces the man's reliability, transforming him into a passive element of a system and limiting his possibility to act. This may have a negative impact on the reliability of the 'pilot–airplane' system in case of a failure of directive devices. So, in the directive control's mode, the automation of piloting signals' processing brings about a reduction of the mental image of a flight. This reduction concerns mainly the sensory–perceptive components of the mental image, which, in turn, leads to an impoverishment of the object-related content of a mental image. A mental image reflects primarily the position of instrumental indexes rather than the airplane's spatial position. The image basic component loses its significance and is not presented in consciousness.

Zavalova *et al*. (1986) argued that the introduction of directive instruments has as its consequence the transformation of the internal psychological content of the process of piloting as a result of the transformation of the action's goal. During the piloting in accordance with a set of devices, the pilot's main goal is to maintain the flight mode, i.e. to keep current flight parameters in conformity with the prescribed ones. If in more difficult flight conditions the pilot's actions are directed to the 'zeroing in' of one arrow on a device, he nevertheless is absolutely conscious that this is a temporary intermediate goal and that this effort cannot bring him success. To maintain the global flight regime is a necessary condition for efficient piloting. In fact, this goal forms the content of an action.

It was shown that piloting in accordance with the directive device reduced the action's goal; the latter transforms into maintenance of the spatial position according to the directive indexes. The fact that this goal is easy to attain and that it leads to success explains its great importance. Pilots are not always guided by their final goal. It is enough for them to achieve one of their intermediate goals of 'zeroing' in indexes. The final goal, which is to maintain flight regime, has no pragmatic value in this case. That is why a pilot often forgets to control an airplane's spatial position. In fact, the spatial position's representation is excluded from the structure of the mental image of a flight.

The other part of the study carried out by Zavalova *et al*. (1986) concerned an analysis of the mental image of a flight that regulates a pilot's activity during the automated flights.

In automated flights, the pilot is left out of the execution of control actions related to the visual tracing of directive signals. He must visually control the accuracy of the automatic pilot and be ready to direct in certain moments as well as at automata failures. In this case, one of the reasons for a mental image reduction, namely the load by a visual tracing, has disappeared. At the same time, a possibility to control a number of devices and to switch attention to their indications appeared. Indeed, the external form of visual control of instruments in automatic mode proved to be similar to the mode of the manual control.

However, this external similarity does not mean a resemblance of internal perceptive structures. The degree of pragmatism of instrumental signals and the level of generalization for piloting information are different in manual and in automatic modes. In the manual mode, the information from each piloting device is necessary for the formation of motor action; at the same time, there is no generalization of piloting signals given to command instruments in directive and automatic modes. So, the pilot is not only supposed to collect information from each piloting device, but also has to process it in order to plan his executive object-oriented actions. This generates a time deficit, which, in turn, has a negative impact on perception structure.

In the automatic mode of control, a pilot arbitrarily regulates the perception of instrumental information and distributes attention between all the instruments according to the information they provide. The automation of executive operations eliminated the objective need for the pilot to exclusively concentrate his attention on the movements of directive indexes that is the objective reason for a mental image reduction. Thus, the pilot has enough time to perceive all the information, necessary for the formation of a fully developed mental image of a flight.

However, automation did not increase the degree of pragmatism of this information. That is why it did not eliminate the internal reason for a mental image reduction. Experiments carried out in flight and on the simulators showed a high probability of mental image reduction in the automatic mode of control (Beregovoy *et al.* 1978).

In the automatic mode, the pilot has more time that is free of action, but also a higher probability of becoming less vigilant. The internal reason for this phenomenon is the reduction of the object-related content of the mental image; its consequences result in some serious pilot mistakes at automata failures. As shown in experimental flights, the result of this incompleteness of an image is that, for ~30–80 s during a landing (i.e. at a dangerous height), pilots have been ignorant of the deviations from the airplane's prescribed spatial position. In simulators, in an automatic mode of control, pilots noticed some of the essential deviations in the flight parameters later than in a manual one when the pilots were more loaded. In the latter case, the detection time was 10-times smaller than in the automatic mode (Zavalova *et al.* 1986).

So, an elimination of the need to continuously trace the directive devices was not the main reason for the reconstruction of the full mental image of a flight. It was experimentally shown that the pilot himself should understand the need to form the spatial position mental image along with the 'fork image' (Zavalova and Ponomarenko 1980, 1984, Zavalova *et al.* 1986). In order to do this, he must be placed under conditions that will help him to realize the practical necessity of a fully developed mental image. In this case, the formation of a mental image gets a subjective sense. One such condition manifests itself in the subjective experiences of a pilot's faulty actions at the directive indexes (e.g. the trajectory computing machine) failures. The warnings about the possibility of mistakes occurring as a result of the false signals transmitting from the directive indexes prove to be insufficient. Pilots simply do not believe in the possibility of such 'stupid' mistakes, knowing that they have all the information for an accurate evaluation of the global flight's regime. An internal need for a constant evaluation of the airplane's spatial position and for the analysis of the devices' indications concerning the flight's mode (such as avia-horizon, course and speed indicators) is created only as a result of one's own mistakes. In order to do this, one has to work out a conscious habit to actively compare the indications of a set of piloting devices with the directive indexes' indications.

Another problem is posed by long-distance automatic flights. This problem concerns a conservation of the flight image's sensory component being the basis of the feeling of an airplane. During long-distance automatic flights, the automatic pilot maintains the constant flight routine and the physical interventions of the pilot are minimized. Thus, the feeling of an airplane can be eliminated from the structure of the mental image of a flight: the pilot uses only its informational model.

As shown by Zavalova *et al.* (1971, 1986), the change of the mental image of a flight during the undisturbed, automatic long flights is conditioned, besides an exclusion of the sensory component of action (as an objective condition), by purely psychological reasons, i.e. the occurring subjective set that an airplane is controlled by an automata. This set changes the pilot's goal-orientation so much that he, in particular: (1) forgets to regulate a speed parameter, though control of speed is not automated and is done manually (2) does not notice essential deviations from the nominal flight mode for quite a long time (~160 s) and this occurs during a presence of all necessary visual information, and (3) intervenes rather late in cases of emergency when manual command is necessary (for example, as a consequence of automata failures) and his executive actions are quite disoriented.

Using experimental results, the authors concluded that in an automatic flight, both in the directive and in the automatic control modes, the reduction of the mental image of a flight is possible: that is, the reduction of this mental image with a complex structure and a rich content to one of its components, regulating the most simple motor acts ('the fork image'). In general, this limits the level of the pilot's activity.

This process imposes specific requirements as to the design of the activity of modern pilots who will work on automated airplanes from the very beginning of their professional careers. Such a design should take into account two aspects: (1) the reduction of reliability of the pilot's actions due to a reduction of the mental image and (2) weakening of work motivation. Real and experimental flights showed that training and technical tools could solve the problem of conservation of the mental image of a flight (Zavalova *et al.* 1986).

Psychological analysis of human activity in an automatic system of control shows that training should be based not only on motor skills even in those professions where the motor acts occupy a great volume of executive actions in terms of time and effort. The basis of human action reliability is the formation of a mental image that regulates the actions. The more automated a process of control is, the more attention should be paid to the formation of a conceptual model in the design of an operator's activity. In fact, the mental image which is necessary for the working out of manual operations' habits and which regulates the executive actions has been formed without any special effort from the trainee. That is why the flight image of a pilot carrying out a control when the automatic process of piloting is taking place, should be worked out by conscious efforts during special education.

8. Characteristics of mental image, regulating human activity in exceptional situations or emergencies

As a rule, the number of signals received in exceptional (emergency) situations does not allow an operator to quickly identify conditions and to find an appropriate action. That is why his reliability depends in many ways on his ability to form a fully-developed operative image by a transformation of incomplete information into something subjectively full and clear and by overcoming a contradictory character of signals. This means that a mental image regulating actions during emergencies should have some specific features and characteristics which distinguish it from a mental image regulating an action in standard flight conditions.

According to Zavalova *et al.* (1986), first, this mental image is formed during an emergency as a new psychic mechanism and not as a result of the development of existing operative images. That is why actions cannot be regulated by mental images formed earlier. Secondly, quite often in human memory there is no ready-to-use referent mental image with which an emergency mental image could be compared. This is related to incompleteness of input information necessary for the formation of an emergency mental image which does not represent a sufficient condition for formation of an object-oriented content. This difficulty may be in part stipulated by an operator's insufficient training. In other words, as a rule, the operator does not have prior training and ready-to-use mental images, allowing him to cope immediately with an exceptional situation. A mental image is formed in a situation itself. It is presented as an image-hypothesis requiring verification before the beginning of executive actions. The authors note that such verification requires additional external information or extraction from the memory of additional components of the referent-image. Thirdly, the main function of a mental image being in the course of formation is identification of a situation, i.e. an analysis of incomplete information and retrieval of relevant situational characteristics confirming the hypothesis. Fourthly, this mental image must be flexible and extremely dynamic (it should guarantee the possibility of change, i.e. a rejection of the hypothesis, if not confirmed).

The studies of pilots' actions in emergency situations (Zavalova *et al*. 1971, 1986) showed that the formation of a pilot's mental image adequate to a task is to a large extent down to chance and that in many cases the formation of an incomplete, useless (and even harmful) operative image which can influence a pilot's actions in concrete situations can occur. Quite often, an accurate operative image adequate to a task is formed only after a cycle of trial and error, which further complicates the difficult flight situation. A number of experiments in which a breakdown of airplane engines was artificially introduced brought forward the following general conclusion: exceptional conditions in which a pilot has to act introduce each time new specific features to the operative images regulating his actions. In some cases (at engines' breakdowns), a generalized (global) and at the same time differentiated referent image is required. It allows for the identification of subtle differences between the input signals and the formation of different hypotheses. In other cases (for instance, in automatic pilot's breakdowns), an unambiguous referent image is necessary, because it becomes possible to fully face the situation. Yet, in some other cases, an operative image should be formed primarily on the basis of the conceptual model, namely the mental image of a flight. Obviously, different typical situations require different training methods and techniques. The pilot's actions during emergencies cannot become the automated skills; only their final and executive component may be subject to automation.

The training to act in emergencies should contain conscious efforts towards the formation of psychic mechanisms capable of action regulation, on the one hand, and of mental images adequate to concretize tasks, on the other hand. In general, pilots should be trained in different methods and techniques of observation (and self-observation) as well as in analysis and the comparison of perceived signals.

9. Conclusion

One of the tasks of this article was to present some aspects of the conception of activity developed in Russian psychology. It is hoped that these aspects will be of interest to the Western reader. One tried to touch upon several points of the concept of activity, developed by Rubinstein, as well as to describe a number of examples of Russian studies concerning the 'Man–technology' problems.

The main part of the article was devoted to an analysis of studies, based on a concept of the mental image as a regulator of human activity. This concept, being very important for Russian theories of activity, seems to be insufficiently presented in Western literature.

A number of concepts discussed in this paper seem to be up-to-date and suitable for a solution of problems, related to studies of human activity in interaction with technology. In particular, the principles of anthropocentric approach are reflected in the development of current approaches and methods, oriented to the user.

Thus, the instrumental approach developed by Rabardel (1995, 1997) emphasizes the subject's central role in his interaction with the object. Instrument is an entity, integrating at the same time both the subject's and artifact's characteristics: this is (1) a material or symbolic artifact and, at the same time (2) a scheme for its use. So, an instrument is a product of a subject's activity, it depends on a subject's goals, tasks of activity, on his past experience, etc. The other aspect of the instrumental approach related to the questions discussed in the present article refers to the relationship between a designer and a user, in particular in an analysis of instrumental genesis. The instrumental approach poses the problem of studying the relationship between the functions of an artifact, put in by a developer, and the functions, created by a user. These two types of function must be taken into account in the development of a new generation of artifacts. Obviously, such a standpoint is one of the possible approaches towards activity designing, i.e. to the perpetual cycle of designing of the tools of human activity and the activity of the subject, using these tools.

This aspect of the anthropocentric approach (i.e. its orientation on a user and on the designing of activity) served as a basis for the studies on a user's activity and a user's evaluation of the perceived environmental characteristics and processes (Nosulenko 1991, Nosulenko and Samoylenko 1999, 2001, Nosulenko *et al.* 2000). According to Nosulenko *et al.*, the processes of object development and use are closely connected, so the problem of perceived characteristics concerns simultaneously these two processes. The perceived characteristics of human activity's objects should be studied in relation to its social and cultural context and to the mediating role of new technologies in the formation of perceptual image; an analysis should concern both a perception of the object and activity's elements during its use. In other words, a simultaneous study of the process of technical object development (i.e. an analysis of developer's representation of the object and a study of his activity), on the one hand, and the process of using this object (i.e. an analysis of user's mental image and a study of his activity), on the other hand, should be carried out. This could urge a developer to think about a user during the different stages of development and to postulate an improvement in the composition of technical systems.

By using the concept of mental image as a regulator of human activity, concrete methods of the evaluation of the quality of goods and services could be proposed. A research paradigm, allowing for an analysis of human perception and activity in the process of object use as well as the quantitative presentation of information about some of characteristics of perceptual image and in comparison with physical parameters of an evaluated object could be also developed (Nosulenko and Samoylenko 1997, 2001).

Acknowledgement

The authors are grateful to Professor Aaron Cicourel from the University of California, San Diego for much help and important remarks in preparation of this manuscript.

References

ANANIEV, B.G. (Ed.), 1959, *Osyazanie v Protsessakh Truda i Poznaniya (A Sense of touch in the Processes of Work and Cognition)* (Moscow: Russian Academy of Pedagogical sciences).

ANANIEV, B.G., 1960, *Psychologiya Tchuvstvennogo Poznaniya (The Psychology of Cognition)* (Moscow: Nauka).

ANANIEV, B.G., 1968, *Tchelovek Kak Predmet Poznaniya (The Man as the Object of Cognition)* (Leningrad: University of Leningrad).

ANANIEV, B.G., 1980, *Izbrannye Psikhologitcheskiye Trudy (Selected Psychological Works)* (Moscow: Pedagogika).

BARABANSCHIKOV, V.A., 2000, S.L. Rubinstein i B.F. Lomov preemstvennost' nautchnykh traditsij (S.L. Rubinstein and B.F. Lomov relationship between scintific traditions). *Psikhologitcheskii Jurnal* (Psychological Journal), **21**, pp. 7–15.

BASSOV, M. YA., 1975, *Izbrannye Psikhologitcheskie Trudy (Selected Psychological Works)* (Moscow: Pedagogika).

BEREGOVOY, G.T., ZAVALOVA, N.D., LOMOV, B.F. and PONOMARENKO, V.A., 1978, *Eksperimentalno-psikhologitcheskie Issledovania v Aviatsii i Kosmonavtike (Experimental Psychological Research in Aviation and Space)* (Moscow: Nauka).

BRUSHLINSKY, A.V. (Ed.), 1997, *Psikhologitcheskaya Nauka v Rossii XX Stoletia: Problemy Teorii I Istorii (Psychological Science in Russia in 20th Century: Problems of Theory and History)* (Moscow: Institute of psychology of Russian Academy of sciences).

COLE, M., 1996, *Cultural Psychology*, pp. 7–15 (Cambridge: Harvard University Press).

DAVYDOV, V.V., 1996, *Teoria Razvivayushego Obutcheniya (The Theory of Development Education)* (Moscow: INTOR).

FRANTSEN, B.S., EGOROV, B.A. and KOSTUK, L.A., 1967, K voprosu o kharaktere psikitcheskogo obraza v letnoj deyatelnosti (About character of the psychic image in the activity of the pilot). *Voprosy Psykhologii* (Questions of psychology), **2**, pp. 71–78.

GALPERIN, P.Y. (Ed.), 1983, Razvitie utcheniya o planomerno-poetapnom formirovanii psikhitcheskoj deyatel'nosti (The development of the ideas on the formation by stages of the psychic activity). In *Aktual'nye Problemy Sovremennoj Psikhologii* (Current problems of contemporary psychology), pp. 134–157 (Moscow: Unuversité de Moscow).

GALPERIN, P.Y., 1998, Psikhologiya kak ob'ektivnaya nauka (Psychology as the objective science). In *Izbrannye psikhologitcheskie trudy* (Selected Psychological works), Vol. 17, D.I. Feldstein (Ed.), pp. 37–448 (Moscow-Voronezh: Academy of Pedagogical and Social Sciences).

GOLIKOV, YU.YA. and KOSTIN, A.N., 1996, *Psikhologia Avtomatizatsii Upravlenia Tekhnikoj (Psychology of Automation of Control of Technique)* (Moscow: Institute of psychology, Russan Academy of Sciences).

GORDEEVA, N.D., DEVISHVILI, V.M. and ZINTCHENKO, V.P., 1975, *Mikrostrukturnyj Analiz Ispolnitel'skoj Deyatel'nosti (Micro-structural Analysis of the Executive Activity)* (Moscow: VNIITE).

HERATEVOLE, Z., 1956, *Psikhologiya Tcheloveka v Samolete (Psychology of Man in an Airplane)* (Moscow: Foreign literature edition).

KONOPKIN, O.A., 1980, *Psikhologitcheskie Mekhanizmy Regulyatsii Deyatel'nosti (Psychological Mechanisms of the Regulation of Activity)* (Moscow: Nauka).

KRYLOV, A.A., 1972, *Tchelovek v Avtomatizirovannykh Sistemakh Upravleniya (Man in the Automated Control Systems)* (Leningrad: University of Leningrad).

LEONTIEV, A.N., 1975, *Activité, Conscience, Personnalité* (Moscow: Editions du Progrès).

LEONTIEV, A.N. and LOMOV, B.F., 1963, Tchelovek i tekhnika (Man and Technology). *Voprosy psykhologii* (Questions of psychology), **5**, pp. 29–37.

LOMOV, B.F., 1963, *Tchelovek i Tekhnika (Man and Technology)* (Moscow: Sovetskoe radio (Soviet Radio)).

LOMOV, B.F., 1975, Sistemnyj podkhod v inzhenernoj psikhologii (Systemics approach in the engineering psychology). *Studia psychologica*, **17**, pp. 86–93.

LOMOV, B.F., 1977, O putyakh postroeniya teorii inzhenernoj psikhologii na osnove sistemnogo podkhoda (About ways of creation of a theory of the engineering psychology in the framework of the systemic approach). In *Inzhenernaya Psikhologiya (Engineering*

Psychology), B.F. Lomov, V.F. Rubakhin and V.F. Venda (Eds), pp. 31–54 (Moscow: Nauka).

Lomov, B.F., 1978, Psychological processes and communication. *Soviet Psychology*, **17**, pp. 3–22.

Lomov, B.F., 1979, Mental processes and communication. In *Soviet and Western perspectives in Social psychology*, L.K. Strikland (Ed.), pp. 211–223 (New York: Pergamon Press).

Lomov, B.F. (Ed.), 1981, *Problema Obscheniya v Psykhologii (Problems of Communication in Psychology)* (Moscow: Nauka).

Lomov, B.F., 1984, *Metodologitcheskie i Teoretitcheskie Problemy Psikhologii (Methodological and Theoretical Problems in Psychology)* (Moscow: Nauka).

Lomov, B.F. and Surkov, E.N., 1980, *Antitsipatsiya v Strukture Deyatel'nosti (Anticipation in the Structure of Activity)* (Moscow: Nauka).

Lomov, B.F., Belyaeva, A.V. and Nosulenko, V.N. (Eds), 1985, *Psykhologitcheskie Issledovaniya Obscheniya (Psychological Studies of Communication)* (Moscow: Nauka).

Nosulenko, V., 1991, Psychological peculiarities and acoustical environment changes. *International Journal of Psychology*, **26**, pp. 623–632.

Nosulenko, V.N. and Rabardel, P., 1997, Psychologie de l'ingénierie, psychologie du travail et ergonomie dans les pays de l'ex-URSS. In *Actes du XXVI Congrès de la SELF*, M.-F. Dessaigne (Ed.), pp. 5–22 (Lyon: GERRA).

Nosulenko, V. and Rabardel, P., 1998, Ergonomie, psychologie et travail dans les pays de l'ex-URSS. (Historicité et spécificité du développement). In *Dés Évolutions en Ergonomie…*, M.F. Dessaigne and I. Gaillard (Eds), pp. 13–28 (Toulouse: Octarès).

Nosulenko, V. and Samoylenko, E., 1997, Approche systémique de l'analyse des verbalisations dans le cadre de l'étude des processus perceptifs et cognitifs. *Informations sur les Sciences Sociales*, **36**, pp. 223–261.

Nosulenko, V. and Samoylenko, E., 1999, Evaluation de la qualité perçue des produits I.S.P. par verbalisations. In *Ergonomie et Télécommunications. Journée satellite du XXXIV-ème Congrès de la SELF*, D. Goujon, G. Poulain, V. Ledounois, D. Berdugo, P. Buissan (Eds), pp. 99–105 (Caen: France Telecom).

Nosulenko, V. and Samoylenko E., 2001, Evaluation de la qualité perçue des produits et services: approche interdisciplinaire. *International Journal of Design and Innovation Research*, **2**, pp. 35–60.

Nosulenko, V., Parizet, E. and Samoylenko, E., 2000, Différences individuelles de perception de bruits de véhicules à moteur diesel. *Revue française de marketing*, **4–5**, pp. 157–165.

Oshanin, D.A., 1966, The operative image of a controlled object in Man-automatic machine system. In *International Congress of Psychology*, *Symposium* 27, 48–57 (Moscow).

Oshanin, D.A., 1973, Predmetnoe dejstvie i operativnyj obraz (Object oriented Action and the operative Image). Unpublished Dissertation, USSR Academy of Pedagogical Sciences, Moscow.

Rabardel, P., 1995, *Les hommes et Les Technologies. Approche Cognitive des Instruments Contemporains* (Paris: Armand Colin).

Rabardel, P., 1997, Des instruments et des hommes: propositions pour une conception centrée utilisateurs. *International Journal of Design and Innovation Reasearch*, **10**, pp. 7–20.

Rubinstein, S.L., 1935, *Osnovy psykologii (Bases of psychology)* (Moscow: Gosutchped).

Rubinstein, S.L., 1946, *Osnovy obschej psykologii (Bases of general psychology)* (Moscow: Gosutchpedgiz).

Rubinstein, S.L., 1957, *Bytie i Soznanie (The Being and Consciens)* (Moscow: USSR Academy of Sciences).

Rubinstein, S.L., 1958, *O Myshlenii i Putyakh Ego Issledovaniya (About Thinking and the Ways of Its Study)* (Moscow: USSR Academy of Sciences).

Rubinstein, S.L., 1997, *Tchelovek i Mir (The Man and the World)* (Moscow: Nauka).

Sztompka, P., 1993, *The Sociology of Social Change* (Oxford: Blackwell).

Touraine, A., 1984, *Le Retour de L'acteur* (Paris: Essai de sociologie).

Tzuvarev, V.I., 1977, Obraz poleta est'! (Flight Image Exist!). *Aviatsiya i Kosmonavtika* (Aviation and Space), **3**, pp. 12–14.

Welford, A.T., 1961, On the human demands of automation: mental work conceptual model, satisfaction and training. *Industrial and Business Psychology*, **5**, pp. 182–193.

Zaporojets, A.V., 1960, *Razvitie proizvol'nykh dvizhenij (Development of voluntary movements)* (Moscow: Academy of Pedagogical Sciences of Russia).

Zavalova, N.D. and Ponomarenko, V.A., 1980, Struktura I soderzhanie psikhitcheskogo obraza kak mekhanizma vnutrennej regulyatsii predmetnykh dejstvij (The structure and contents of the psychic image as a mechanism of regulation of the object-directed actions). *Psikhologitcheskii jurnal* (Psychological journal), **1**, pp. 5–18.

Zavalova, N.D. and Ponomarenko, V.A., 1984, Spetsifika psikhitcheskogo obraza, reguliruyuschego dejstvia tcheloveka v usloviyakh iskazhennoj afferentatsii (The specificity of the psychic image controlling the actions under the condition of deformed afferentation). *Voprosy psykhologii* (Questions of Psychology), **2**, pp. 26–35.

Zavalova, N.D., Lomov, B.F. and Ponomarenko, V.A., 1971, Printsip aktivnogo operatora i raspredelenie funktsij mezhdu operatorom i mashinoj (Principle of the active operator and the distribution of functions between an operator and a machine). *Voprosy psykhologii* (Questions of Psychology), **3**, pp. 3–15.

Zavalova, N.D., Lomov, B.F. and Ponomarenko, V.A., 1986, *Obraz v Sisteme Psykhitcheskoj Regulya Tsii Deyatel'nosti (The Image in the System of Mental Regulation of the Activity)* (Moscow: Nauka).