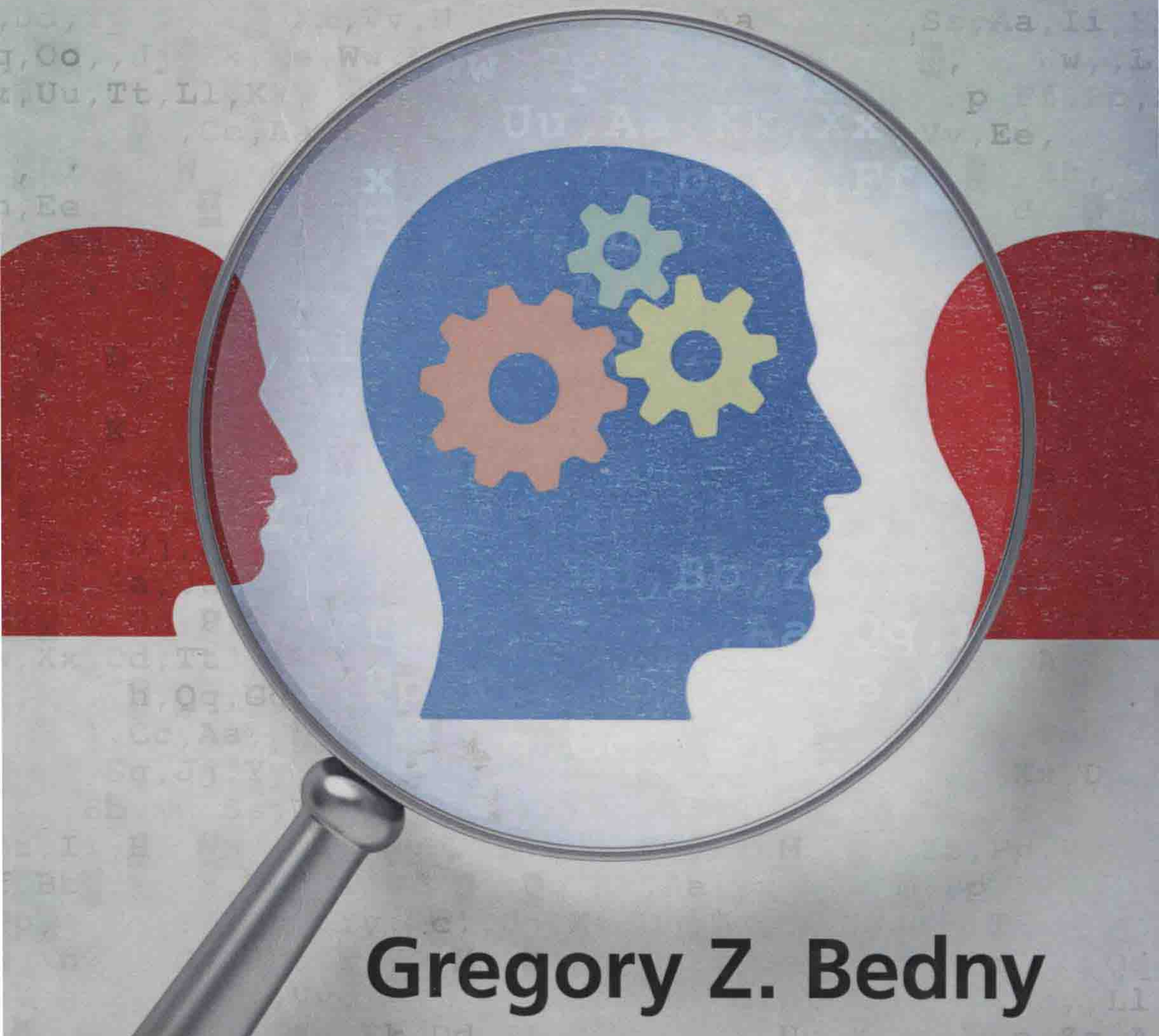
# Application of S[illegible]ic-Structural Activity Theory to Design and Training



Gregory Z. Bedny

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# Preface

Currently, every complex human–machine system includes a computer as a critically important means of work. However, an operator's interaction with a computerized system cannot be reduced to only performing computer-based tasks. When working with such systems, an operator often monitors and, if needed, enters a control loop to override an automated system response to situational events. For example, manual control is used in the more complicated stages of flight such as takeoff and landing and during system failure. Current developments in the production domain do not eliminate manual components of work. An example of such type of work is complex assembly tasks in contemporary manufacturing. These tasks do not require significant physical efforts but rather use complex technological tools and perform high-precision motor activity in combination with cognitive actions. This makes the performance time of motor components of activity and its relationship with precision an important topic in ergonomics and engineering psychology. Virtual reality techniques become increasingly popular for determining the efficiency of task performance and training in contemporary industry. This book concentrates on discussing such type of work when an operator performs various tasks in highly automated technological systems and interacts with various displays and controls. It also includes consideration of certain aspects of analysis of computerized tasks. At the same time, manual components of work in contemporary industry are also considered.

Cognitive approach considers work analysis and design from information processing perspectives. It focuses on analyzing the constraints that cognition imposes on human performance (Vicente, 1999). With this viewpoint in mind, researchers start task analysis by describing the subject's cognitive characteristics. Cognition is considered as a system of cognitive processes and is presented as an information-processing model. However, cognition is not just a system of cognitive processes that can be described as a sequence of specific stages. It is also a structure that can be presented as a system of cognitive actions and operations that are basic elements of mental activity. Thus, it can be described as a cognitive structure that has a complex relationship with the environment (configuration of equipment, human–computer interface, and social reality). This structure is not a static system. It has dynamic characteristics and is organized depending on the specifics of external conditions and strategies of the subject's activity. Such characteristics of cognition are entirely ignored by the cognitive approach. As Kuutti (1997, p. 19) correctly pointed out, this approach uses experimental laboratory-oriented classical psychology methods that are unable to penetrate the human side of the interface. In practice, the cognitive approach is replaced by experimental procedures similar to the black box approach or input–output analysis. Information-processing models are not task specific. They cannot describe the cognitive structure of activity during task performance due to the fact that cognitive psychology has no clearly developed terminology. Such terms as overt actions, cognitive steps, goals, self-regulation, and strategies can be interpreted differently by various professionals in the field. All of this makes it impossible to describe the flexible cognitive and behavioral structure of activity during task performance. SSAT overcomes these limitations in cognitive psychology and considers cognition as a process and as a structure. The cognitive approach is a parametric method of study that should be accompanied by the systemic approach developed in SSAT.

The book presents new theoretical approaches and principles to study human work from the perspective of systemic-structural activity theory (SSAT). This theory provides a unified framework to ergonomics and work psychology. It can be useful for engineers and economists who work in such fields as equipment design, efficiency of human performance, safety, and training. The book is important because it overcomes the traditional separation between cognition, behavior, and motivation using a systemic approach to the analysis of human work activity. The conceptual apparatus of this approach differs significantly from existing approaches outside of activity theory. The book starts with comparative analysis of general, applied, and systemic-structural activity theory. The author has taken into account the difficulties faced by professionals when they try to use activity theory and presented basic concepts such as goal, relationship between goal and motives, mechanisms of anticipation, vector motive → goal, and cognitive and behavioral actions. The concept of task is considered from the SSAT perspective. Here, for the first time, activity theory terminology is examined not only from a psychological perspective but also from a neurophysiologic perspective.

There is no unified and standardized psychological terminology that can be applied to ergonomic design. The same terms carry different meanings when utilized by different authors. The terminology used in activity theory in recent studies is clarified, and the terminology used in some new psychological approaches that utilize activity theory as a starting point in their development is compared and refined.

Section II has five chapters. In Chapter 5, knowledge and skill acquisition processes are discussed from the SSAT perspective. SSAT offers the following basic principles of learning: unity of cognition, behavior, and motivation; learning as a complex goal-directed self-regulative process that integrates conscious and unconscious levels of self-regulation; learning process as a transition from a less efficient to a more efficient strategy of activity performance; and the ability of a learner to achieve the same goal by various strategies. Learning curve analysis is considered as an efficient tool for studying various tasks in the production environment. The shape of the learning curve is affected by the nature of the task, the idiosyncratic features of the trainee, and the training method. Task analysis during its acquisition is known as a genetic method of study in activity theory. The essence of this principle is to study various psychological phenomena during their development. Cognition and structure of activity in general is studied based on the analysis of the sequential stages of its formation, reconstruction, and dialectic genesis. Thus, studying the acquisition process is a very useful method, which is illustrated by applying it to the analysis of various types of task, including computer-based tasks. In this section, the data in learning by observation are presented.

In Chapters 6 and 7, the data on the design of human–machine system are discussed. The term *design* takes its roots in engineering and cannot be reduced to experimentation as it is done in cognitive psychology. The main objective of design is to create an appropriate documentation that describes a designed object. For example, in manufacturing at the analytical stage, various drawings of the same object are developed and accompanied by related quantitative assessment. The next stage includes creation of a prototype and experimental evaluation of a designed object. The obtained data are further used for the adjustment of the models (drawings and quantitative analysis), and the cycle can be repeated. The engineering design process can be presented as follows: nonformalized (qualitative) stage → formalized stage (drawings and calculations) → experimental stage (experimental evaluation of a prototype). The application of similar methodology to ergonomic design of complex human–machine systems is considered in this book.

Special attention is paid to designing flexible tasks that are performed by an operator in semiautomatic and automatic systems where a complex combination of cognitive and motor components of activity prevails. Similar to engineering design, in SSAT any design involves qualitative and analytical stages. In this section, attention is paid to the first three stages of design and especially to the qualitative stage of analysis that considers human activity as a goal-directed self-regulated system. The process of self-regulation is described as different stages of information processing. These stages have loop structure organization. Each stage is called a function block, because it performs a particular function in activity regulation with forward and backward interconnections between different function blocks. The application of the concept of self-regulation to the analysis of the pilot's activity in emergency situation is considered along with the relationship between time study, error analysis, and design. The formation of professional pace during task performance is discussed. Chaper 9 demonstrates the application of queuing theory to human error analysis, offering quantitative methods for the assessment of human performance in time-restricted conditions.

Section III contains three chapters and describes the basic quantitative analytical method of task evaluation from the SSAT perspective. This method includes the quantitative assessment of task complexity in human–machine systems. Task complexity is a psychological characteristic of task that determines cognitive demands for task performance. The relationship between task complexity and task difficulty is discussed. A critical analysis of some methods of task complexity evaluation outside of SSAT is presented. It is demonstrated that these methods ignore the complex structure of activity that unfolds in time as a process. As a result, such methods utilize incommensurable units of complexity measures. In this section, we demonstrate how the task complexity evaluation method developed in SSAT can be used for the analysis of production operations and evaluation of tasks in highly automated human–machine systems. Task complexity evaluation is an important tool for the optimization of task performance and for equipment design. Complexity evaluation of such tasks has some specifics in comparison with task complexity evaluation of computer-based tasks. In Chapter 12, we demonstrate how task complexity evaluation can be used for safety analysis. This is a totally new method in this area of study. This approach allows detecting errors not by observation or experiment but by just utilizing models of human work activity. This can support more effective safety analysis and help predict possible errors in the early stages of a design process. The developed approach to task complexity and safety evaluation is important for ergonomics, work psychology, engineering, and economics.

It is well known that the effectiveness of all quantitative analytical methods in psychology and ergonomics has been quite limited to this point. In contrast, as described in this book, methods are brought to the level of practical application. This book has the potential to significantly affect the development of work psychology and ergonomics and can be useful for industrial engineers, computer professionals, designers, and specialists in safety and training. SSAT can be considered as one of the main approches to the study of human performance and work design. This book also provides the reader with state-of-the-art information in SSAT and demonstrates its application to task analysis, design, and training.

# *Author*

**Dr. Gregory Z. Bedny** worked as a professor at several Ukrainian universities, and after arriving in the United States taught at Essex County College in New Jersey. He has now retired and is a research associate at Ergologic, Inc. He earned his doctorate degree (PhD) in industrial organizational psychology from Moscow Educational University and his post-doctorate degree (ScD) in experimental psychology from the National Pedagogical Academy of Science of the Soviet Union. Dr. Bedny is a board-certified professional ergonomist (BCPE). He also is an honorary academician of the International Academy of Human Problems in Aviation and Astronautics in Russia and an honorary doctor of science of the University of South Ukrainian. He has been awarded an honorary medal by the Ukrainian Academy of Pedagogical Sciences for his achievement in psychology and his collaborative works with Ukrainian psychologists.

Dr. Bedny is the founder of the systemic-structural activity theory (SSAT). SSAT is a high-level generality theory or framework that is the basis for unified and standardized methods of studying human work. He authored a number of original scholarly books and multiple articles in this field. He applied his theoretical study in the field of human–computer interaction, manufacturing, merchant marines, robots systems, work motivation, training, fatigue reduction, etc.

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