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Activity Theory: Implications for Human-Computer Interaction

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Recently interest has grown in applying activity theory, the leading theoretical approach in Russian psychology, to issues of human-computer interaction. This chapter analyzes why experts in the field are looking for an alternative to the currently dominant cognitive approach. The basic principles of activity theory are presented and their implications for human-computer interaction are discussed. The chapter concludes with an outline of the potential impact of activity theory on studies and design of computer use in real-life settings.

THE NEED FOR A THEORY OF HUMAN-COMPUTER INTERACTION

It is generally accepted that the lack of an adequate theory of human-computer interaction (HCI) is one of the most important reasons that progress in the field of HCI is relatively modest, compared with the rate of technological development. People coming to the field of HCI from different disciplines—psychology, computer science, graphics design, and others—have serious problems in coordinating and combining their efforts. For example, typical HCI curricula for undergraduate and graduate students present a mixture of knowledge from various disciplines rather than an integrated perspective.

Traditional conceptual approaches cannot provide an appropriate basis for addressing many important aspects of HCI, including computer-supported cooperative work (CSCW) and cross-cultural aspects of computer use. Consequently the impact of HCI studies on current design practice is limited, with user interface design being based mainly on intuition and expensive trial and error.

The form of a suitable HCI theory has been subjected to much debate recently (Carroll, Kellogg, and Rosson 1991). A major trend in the debate has been the growing dissatisfaction with the dominant cognitive approach (Bannon 1991; Wood 1992; Monk et al. 1993). In contrast to the general agreement that current attempts to apply cognitive psychology to HCI are not very successful, there is little agreement on the most promising theoretical alternatives. Proposals vary from an enrichment of the traditional cognitive scheme (Barnard 1991) to a radical shift in paradigms, for example, from scientific experimental studies to ethnographic methodology (see Monk et al. 1993).

In this period of theoretical uncertainty there has been a growing interest in activity theory, greatly stimulated by Bødker's works (1989, 1991). She was the first Western researcher who presented the basic ideas and potential benefits of activity theory to the HCI community. Recently, a number of papers discussing the activity theory approach to HCI have appeared in major international journals and conference proceedings (Bannon and Bødker 1991; Draper 1993; Kaptelinin 1992a; Kuutti 1992; Kuutti and Bannon 1993; Norman 1991; Raeithel 1992; Wood 1992; Nardi 1992).

The aim of the present chapter is to summarize current work in activity theory and its implications for the field of human computer-interaction. It examines the main differences between activity theory and cognitive psychology, reviews recent attempts to apply activity theory to HCI, and outlines some directions for further development.

FROM COGNITIVE PSYCHOLOGY TO CONTEXTUAL ANALYSIS OF HCI

According to cognitive psychology, the human mind is a specific type of an information processing unit. Various architectures of human cognition have been proposed, all differentiating among three basic modules or subsystems: (1) a sensory input subsystem, (2) a central information processing subsystem, and (3) a motor output subsystem. Another fundamental idea underlying most cognitive models is that of levels

of processing. Essentially this is the dimension of concreteness-abstractness. Input and output represent low levels of human information processing since they deal with the ``raw'' data of external reality. Higher-level processing provides identification and classification of these data, as well as their assimilation into mental representations, understanding, analysis, decision making, and so forth. For a specific action to be made, abstract goals and strategies must be formulated in a concrete form. In other words, the information is processed in both directions: from reality to models and from models to reality.

The theoretical constructs of cognitive psychology have direct analogies in computer science, and the difference in terminology used in these two disciplines is minimal, which was a major factor contributing to the dominant role of cognitive psychology in HCI.

From the traditional cognitive point of view, the HCI system is composed of two information processing units, the human being and the computer, so that the output of one unit enters the other's input, and vice versa. In other words, human-computer interaction can be described as an information processing loop (figure 5.1). The advantages of this scheme are rather obvious. First, it provides a coherent description of the whole system of human-computer interaction within the information processing framework. Second, it structures the problem space of HCI in a useful way. Aspects of human-computer interaction, such as presentation of the information to the user, the user's perceptions, mental models, the user's control of the system, input devices, and user interface versus functionality of the system, can be easily located within this scheme.

The idea of levels of processing has also influenced studies of HCI. For instance, many researchers were influenced by the hierarchical structure of the human-computer interface proposed by Moran (1981). He identified five levels: the task level, the semantic level, the syntactic level, the level of interaction, and the level of physical devices. This structure is explicitly design oriented; it is supposed to support an analogy with top-down programming in user interface design.

It appears that cognitive psychology can be successfully applied to a number of HCI problems. However, this approach has some limitations. An important one is that the ``ecological validity'' of cognitive psychology is questionable (Neisser 1976).

The information processing loop is closed, so it is difficult to take into consideration the phenomena that exist outside it. It is obvious, however, that human-computer interaction can be understood only within a wider context. People use computers to create documents, to communicate with others, and for other purposes, but the main reason is that they seek to achieve some goals that are meaningful beyond actual computer use. Essentially, the ``task level,'' according to the hierarchy proposed by Moran (1981), is supposed to put computer use into the right global context. Yet the relevant concepts and procedures were not articulated by Moran specifically enough, and HCI models based on his ideas (Nielsen 1986; Clarke 1986) are just models of the closed information processing loop (or a hierarchy of virtual loops).

There is an emerging consensus that the cognitive approach to HCI may be limited. It does not provide an appropriate conceptual basis for studies of computer use in its social, organizational, and cultural context, in relation to the goals, plans, and values of the user or in the context of development. In consequence, current studies of HCI that concentrate not only on the low-level events of computer use but on the higher-level events as well (Grudin 1990) require an appropriate theoretical framework in which to analyze the context of computer use.

Among the several candidate approaches, including situated action models and distributed cognition, activity theory (see Nardi, this volume, chapter 4) holds the best conceptual potential for studies of human-computer interaction.

BASIC PRINCIPLES OF ACTIVITY THEORY

The general philosophy of activity theory can be characterized as an attempt to integrate three perspectives: (1) the objective, (2) the ecological, and (3) the sociocultural. Like cognitive psychology, and unlike some other approaches in psychology, activity theory tends to be a ``real,'' that is, a ``natural sciencelike,'' theory. Like Piaget's (1950) and J. J. Gibson's (1979) approaches, and unlike traditional cognitive psychology, activity theory analyzes human beings in their natural environment. Moreover, activity theory takes into account cultural factors and developmental aspects of human mental life (Bødker 1991; Leont'ev 1978, 1981; Wertsch 1981).

The most fundamental principle of activity theory is that of the unity of consciousness and activity. ``Consciousness'' in this expression means the human mind as a whole, and ``activity'' means

human interaction with the objective reality. This principle, therefore, states that the human mind emerges and exists as a special component of human interaction with the environment. Mind is a special ``organ'' that appears in the process of evolution to help organisms to survive. Thus, it can be analyzed and understood only within the context of activity.

The next principle is object-orientedness. This principle specifies the activity theory approach to the environment with which human beings are interacting. Unlike Piaget and Gibson, activity theorists consider social and cultural properties of the environment to be as objective as physical, chemical, or biological ones. These properties exist regardless of our feelings about them. ``The object is a book'' is no less an objective property of a thing than ``the surface of the object mostly reflects the light of the red spectrum'' (that is, that the object is ``red'').

So human beings live in an environment that is meaningful in itself. This environment consists of entities that combine all kinds of objective features, including the culturally determined ones, which, in turn, determine the way people act on these entities. The principle of object-orientedness is an obvious contrast to the assumption behind the cognitive approach that the human mind contacts reality only through low-level input-output processes.

The third basic principle of activity theory is the hierarchical structure of activity. Activity theory differentiates between processes at various levels (or, rather, groups of levels), taking into consideration the objects to which these processes are oriented. *Activities* are oriented to motives, that is, the objects that are impelling by themselves. Each motive is an object, material or ideal, that satisfies a need. *Actions* are the processes functionally subordinated to activities; they are directed at specific conscious goals. According to activity theory, the dissociation between objects that motivate human activity and the goals to which this activity is immediately directed is of fundamental significance. Actions are realized through *operations* that are determined by the actual conditions of activity.

The importance of these distinctions is determined by the ecological attitude of activity theory. In a real-life situation, it is often necessary to predict human behavior. For this purpose it is of critical importance to differentiate among motives, goals, and conditions. In particular, people behave differently in different situations of frustration. When operations are frustrated (that is, familiar conditions are changed), people often do not even notice and automatically adapt themselves to the new situation. When a goal is frustrated, it is necessary to realize what to do next and to set a new goal. This is often done without much effort and without any negative emotion. Also, it is possible to predict what the new goal will be, provided that the motive remains the same. But when a motive is frustrated, people are upset, and their behavior is most unpredictable.

In consequence, to understand and to predict the changes of people's behavior in different situations, it is necessary to take into account the status of the behavior in question: is it oriented to a motive, a goal, or actual conditions? This is why activity theory differentiates among activities, actions, and operations. The criteria for separating these processes are whether the object to which the given process is oriented is impelling in itself or is auxiliary (this criterion differentiates between activities and actions), and whether the given process is automatized (this criterion differentiates between actions and operations).

The fourth principle of activity theory, that of internalization-externalization (Vygotsky 1978), describes the mechanisms underlying the originating of mental processes. It states that mental processes are derived from external actions through the course of internalization.

The concept of internalization was also introduced by Piaget, but the meaning of this concept within activity theory is somewhat different. According to Vygotsky (1978), internalization is social by its very nature. The range of actions that can be performed by a person in cooperation with others comprises the so-called ``zone of proximal development.'' In other words, the way human beings acquire new abilities can be characterized as ``from *inter-subjective* mental actions to *intra-subjective* ones.'' The opposite process of internalization is externalization. Mental processes manifest themselves in external actions performed by a person, so they can be verified and corrected, if necessary.

The fifth principle is mediation. Human activity is mediated by a number of tools, both external (like a hammer or scissors) and internal (like concepts or heuristics). These tools specify their modes of operation, that is, those developed over the history of society. The use of these culture-specific tools shapes the way people act and, through the process of internalization, greatly influences the nature of mental development. Tools are thus the carriers of cultural knowledge and social experience. Tool mediation is no less an important source of socialization than formal education is.

The mechanism underlying tool mediation is the formation of ``functional organs,'' the combination of natural human abilities with the capacities of external components—tools—to perform a

new function or to perform an existing one more efficiently. For example, human eyes equipped with glasses compose a functional organ that provides better vision.

The last (but not least!) principle is the principle of development. According to activity theory, to understand a phenomenon means to know how it developed into its existing form. The principle of development gives an opportunity to conduct thorough, scientific analysis of complex phenomena while avoiding mechanistic oversimplifications.

These principles are not isolated ideas. They are closely interrelated; the nature of activity theory is manifested in this set of principles taken as an integrated whole.

ACTIVITY THEORY AND HUMAN-COMPUTER INTERACTION

According to activity theory, the computer is just another tool that mediates the interaction of human beings with their environment. The only way to come to an adequate understanding of human-computer interaction is to reconstruct the overall activity of computer use. As Kuutti (1992) argued, activity provides a ``minimal meaningful context'' for human-computer interaction. The questions that arise when computer use is considered from the point of view of activity theory are the following: What is the hierarchical level of human-computer interaction within the structure of activity? Does computer use correspond to the level of particular activities, to the level of actions, or to the level of operations? Which tools, other than computerized tools, are available to the user? What is the structure of social interactions surrounding computer use? What are the objectives of computer use by the user, and how are they related to the objectives of other people and the group or organization as a whole?

These questions may seem to be too global and loosely related to the practice of user interface evaluation and design. However, when these questions are ignored, undesirable consequences may follow; for example, there may be a low level of software usability (Grudin 1991a, 1991b) or software not suited to a specific culture (Borgman 1992).

Another general idea directly relevant to the field of human-computer interaction is that of development. The importance of analyzing computer use within a developmental context is relevant to both the individual level and the group or organizational level. An assimilation of new technologies causes new tasks to emerge (the so-called task-artifact cycle, according to Carroll, Kellogg, and Rosson 1991). A possible way to cope with unpredictable structural changes in a user's activity is to support users in customizing the system according to their current needs (Henderson and Kyng 1991). Yet this is not a universal solution because users often need substantial assistance even in formulating their own needs. Thus, a conceptual analysis of the basic factors and regularities of organizational development is needed to predict this development and to provide an efficient use of information technologies.

The development of individual expertise is also an important factor that is not adequately addressed by the cognitive approach. Cognitive models of skill acquisition, based on ideas of procedural knowledge compilation or chunking, have trouble accounting for the qualitative changes that cognitive skills undergo in the process of development (Kaptelinin 1992b). Yet these very transformations can be studied and predicted from the standpoint of Bernshtein's (1967) theory, which is usually closely associated with activity theory.

The tool mediation perspective suggests a structure for human-computer interaction that is radically different from the information processing loop. The components of the structure should be not only the user and the computer but also the object the user is operating on through the computer application and the other people with whom the user is communicating (Bødker 1991).

The tool mediation perspective means that there are actually two interfaces that should be considered in any study of computer use: the human-computer interface and the computer-environment interface (figure 5.2).

Interface in the traditional sense is not only a border separating two entities but also a link that provides the integration of a computer tool into the structure of human activity. The mechanisms underlying this integration can be understood from the point of view of activity theory as the formation of a functional organ. It means therefore, that computer applications are the extensions of some precomputer human abilities. One of the most important functions of computer tools in the structure of human activity seems to be the extension of the cognitive structure referred to within activity theory as the internal plane of actions (IPA). The equivalent of the IPA within the cognitive tradition is the mental space where mental

models are located. Its function is to simulate potential outcomes of possible events before making actions in reality.

In sum, activity theory provides a wider theoretical basis for studies of human-computer interaction than does cognitive psychology. It can take account of social interactions and cultural factors, the developmental aspects, and higher-level goals and values. At the same time, this conceptual framework does not reject the experimental results and techniques accumulated within the cognitive tradition. According to Michael Cole, ``U.S. standard cognitive psychology is a reduced subset of a cultural-historical activity approach—without realizing it'' (Cole, personal communication, October 1992). Actually, if we compare the information processing loop (figure 5.1) and the tool mediation scheme (figure 5.2), we can see that the former can easily be placed in the context of the latter.

PROSPECTS FOR THE FUTURE

One fundamental difficulty related to building up a theory of human-computer interaction is the changing nature of the subject matter of the study. In contrast to physical laws, the laws of human-computer interaction are not necessarily invariant over time. When the current methods, styles, and standards are used, the results are inevitably obsolete soon after they are formulated. Activity theory puts HCI into the context of basic, invariant principles underlying human activity, so it provides a better chance for creating a theoretical framework that has a predictive potential.

Attempts to apply activity theory to the field of HCI have been made only recently. In my view, there are good reasons to expect more tangible results from activity theory in the coming years. First, I believe a new model of human-computer interaction will replace the information processing loop underlying the cognitive approach. This model will identify and present in a thorough way the most important aspects of computer use by individuals and by groups and organizations. This model will, I hope, provide various parties involved in the study and design of human-computer interaction with a framework that can make their mutual understanding and cooperation more efficient.

Activity theory can influence the methodology, analysis, and evaluation of human-computer interaction. Bødker's results (this volume) can be considered a first step toward the development of methods that provide the opportunity to organize appropriate field observations or laboratory studies and to obtain valid and reliable data relevant to real-life contexts.

Finally, activity theory can make an important impact on the development of design support tools. The design of a new interactive system involves the design of a new activity—individual or organizational. However, even the perfect design of an ideal activity does not guarantee the success of a system. The transformation of an activity from an initial to a target state can be difficult and even painful. Activity theory can be used to develop a representational framework that will help designers to capture current practice and build predictive models of activity dynamics. Such conceptual tools would enable designers to achieve appropriate design solutions, especially during the early phases of design.

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Figure 5.1
The information processing loop of human-computer interaction.

Figure 5.2
Two interfaces in human-computer interaction.