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Activity Theory as a potential framework for human-computer interaction research

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Abstract

During the recent years the mainstream framework for HCI research — the information-processing cognitive psychology — has gained more and more criticism because of serious problems in applying it both in research and practical design. In a debate within HCI research the capability of information processing psychology has been questioned and new theoretical frameworks searched. This paper presents an overview of the situation and discusses potentials of Activity Theory as an alternative framework for HCI research and design.

1. Introduction

Human-Computer Interaction (HCI for short) has existed for quite a long time as a research domain and gained a reputation as one of the central elements in designing computer applications. There exist several international journals covering the domain, several international conferences have been held every year and a huge number of books on the topic have been published. Many, if not most, curricula for software design professionals contain a course in HCI. Given this record, one would assume that there exists a well-established body of harmonious scientific knowledge covering the basic foundation of the discipline. At first sight this belief seems to be valid, because apparently HCI seems to be based on the application of the information processing branch of cognitive psychology: "The chapters in this volume provide an interim report on the project of establishing an applied science of human-computer interaction grounded in the framework of cognitive science" (Carroll, 1987, p. ix-x).

This harmony is, however, fallacious. Research is not ahead of practice - on the contrary. In fact: a considerable part of recent research is studying successful solutions in order to understand why they are working. We can take "direct manipulation" here as an example. This type of interaction was used in practice already during the 1960s and there were working commercial products during the 1970s, but it was not before the 1980s until research started to gain some grasp of the phenomenon (e. g. Hutchins, Hollan, & Norman, 1986). Still the research is unable to provide founded advice on how such interfaces should be developed.

It is also quite difficult to speak about the cumulation of knowledge - a feature usually connected with "mature sciences" - because the field consists of fragmented subareas, between which it is often difficult to find any coherence or connections.

There is a well-known gap between research results and practical design. (Bellotti, 1988) surveyed English software designers in leading software houses and found that they were not using any results, methods or recommendations derived from HCI research - many of them were unaware of the existence of such. The contents of HCI handbooks aimed at

practical designers are mostly in good harmony with that result: although almost all books have a chapter or two about "theoretical background" - usually simple cognitive psychology - it is difficult to find any connection between these and the "practical guide-lines" offered in the rest of the books. Often the only proposal with some theoretical connection is a demand to take into account the limited abilities of the human brain as an information processor. The guide-lines then are usually derived from practical experience and there is no connecting background model behind them. Thus they suffer from fragmentation, incoherence and context-sensitivity, which all need to be cured by adding more guide-lines to them etc. The largest sets already contain of hundreds of guide-lines with very little internal structure and are most certainly impossible to be used in practice.

Thus it is obvious that there exist lots of systems where interface has not been an object of explicit design, but which, despite that, can serve their users well enough to be in continuous use. On the other hand, some of the most remarkable new interfaces have been developed practically without any help from research into cognitive psychology: "... some of the most seminal and momentous user interface design work of the past 25 years made no explicit use of psychology at all" (Carroll, 1991, p.1).

2. Rising criticism

This state of affairs is obviously not very satisfying, and during the late 1980s a debate against the use of information processing psychology as the foundation of HCI has surfaced, criticizing even the very basic assumptions. Examples of existing problems and corresponding criticism can be found e. g. in (Bannon, 1991a; Bannon, 1990; Bannon, 1991b; Bødker, 1990; Ehn, 1988; Suchman, 1987; Thomas & Kellogg, 1989; Whiteside & Wixon, 1987; Winograd & Flores, 1987). Both the object and methods of the "mainstream" research has been questioned. Critics would like to add to the research object the users and their work tasks in real life. Methodologically the "Cartesian" ideal of cognitive science - continuing the use of experimental apparatus of laboratory-oriented classical psychology borrowed from natural sciences - has been seen unable to penetrate the human side of the interface. So now, in the midst of 1990s we have both the established, cognitive science - based "orthodoxy" and the emerging, although diverse "opposition". Although it is certainly too early to speak of a shift in paradigm, we are anyhow witnessing some kind of crisis in HCI research area. The development of the criticism can easily be studied by comparing two collections of HCI research articles. They have been published only four years apart and edited by same person, namely John C. Carroll, a well-known and productive member of the HCI research community. The collections are: "Interfacing Thought- Cognitive Aspects of Human-Computer Interaction (Carroll, 1987) and "Designing Interaction - Psychology at the Human-Computer Interaction (Carroll, 1991).

How do these books differ from each other? In the earlier one, the possibilities and prospects of cognitive psychology are mostly seen in a rosy light: "... it also represents a rather unusual opportunity for cognitive science: the opportunity to change future technology by producing an understanding of contemporary technology and thereby perhaps to affect the future directly and constructively" (Carroll, 1987, preface p. xiv). Maybe the only place where considerable criticism can be found is the polemic commentary by Whiteside and Wixon at the end of the book. They evaluate the benefits of the book from the viewpoint of practical design. Their view is much less optimistic than elsewhere in book and they are somewhat disappointed with how little help research is giving to practice: " What systems have already been affected by the work described here and similar work that led up to it? In what time frame will the profound influence on interface design be felt?" (Whiteside & Wixon, 1987, p. 355). They also suggest future venues for research, like these subtitles of the paper show: "Could we study HCI in a richer context? - Why not tackle real systems? - Explore alternatives to studying people as objects to be modeled. - Address the political realities of system design."

Four years later the overall tone has changed considerably. The former critics have now the leading voice - all the authors are unsatisfied about the state of affairs and searching ways to change it. The alleviation of the problems is sought either from expanding and enriching current cognitive psychology or by starting totally new approaches. "Currently, a reanalysis of HCI as a practical and scientific endeavour is underway. This reanalysis incorporates (at least) these three aspects: (1) reconceiving the relationship between psychological science and HCI design to be one of interaction, (2) integrating richer and more diverse areas of psychology into HCI, and (3) taking the process and products of design more seriously" (Carroll, 1991, p. 74). During this effort several of the basic assumptions of current HCI research have to be reevaluated: "However, many of the chapters [of the book] advocate and develop more radical proposals. On one hand, they argue that we need to apply approaches to psychology beyond information processing psychology, and perhaps social and behavioural sciences beyond psychology. On the other hand, they argue that information processing psychology itself must be fundamentally enriched as a science base" (Carroll, 1991, p. 5).

What kind of problems and pressures are causing the criticism and movement away from "mainstream" information processing psychology?

3. The nature of perceived problems and the direction of change

Liam Bannon has in his visionary paper (Bannon, 1991b) presented a set of problematic issues in the "mainstream" HCI research which should be remedied. One of the problems he recognizes is expressed in the title of the paper: "From Human Factors to Human Actors". According to Bannon, one of the most characterizing features of the on-going change is a new vision of human beings as active actors and not only as collections of attributes of cognitive processors - a view not unusual in the mainstream cognitive psychology. "Within the HF (human factors) approach, the human is often reduced to being another system component with certain characteristics, such as limited attention span, faulty memory, etc., that need to be factored into the design equation for the overall human-machine system. This form of piecemeal analysis of the person as a set of components de-emphasizes important issues in work design. Individual motivation, membership in a community of workers, and the importance of the setting in determining human action are just a few of the issues that are neglected" (Bannon, 1991b, pp. 27-28). "By using the term *human actors* emphasis is placed on the person as an autonomous agent that has the capacity to regulate and coordinate his or her behaviour, rather than being simply a passive element in a human-machine system" (Bannon, 1991b), s. 29).

There are also other trends Bannon has been recognizing in the recent HCI research. One of them is connected with problems with predetermined fixed requirements for products have caused developers to recognize that to understand what is really needed in the situation it must be worked out with users - which may be a long, cooperative process, not just an initial asking of some questions.- instead of one separated individual it has been largely recognized that features of cooperation, communication and coordination are often vital in the successful performing of tasks. Thus HCI research seeking practical relevance can not restrict itself only to the study of individual acts.

Another issue he has found is the diminishing reliance to laboratory experiments: restricted and artificial laboratory experiments have been in favour in much of the HCI research, but there exists a certain tendency to move closer to real work practices and actual demands they pose. "That is, starting with a focus on interface, the subject matter inevitably expands to encompass the complete working circumstances that occasion and motivate the human interaction with the machine" (Henderson, 1991, s. 257).

Third issue has been the growing recognition that use of the systems is in real life a long-term process that cannot be adequately understood by studying just the initial steps of it. A large part of HCI research has studied only inexperienced users and usually during a relatively short period. In real life people develop their skills during longer periods and this skill-achieving dynamics and its factors have got too little emphasis in research.

Bannon has also found evidence that emphasis in design has been increasing. HCI research has many times concentrated on evaluating some features of existing designs and judging their appropriateness in the situation. Design would, however, need more advice on how to do those features right already in the design phase, not afterwards.

The willingness to involve users into the design process has been growing and that has led towards iterative design. When the problems in system use seriously surfaced during the 1980s, a term "user-centered" was taken into use to describe that designers have to study user populations much more carefully than it had been usual. Studying users from "outside" by designers is not enough, however, but users must be involved into the design process itself. When users are drawn into the design process, it is not self-evident, however, that they can easily articulate the real demands of situations, because they do not usually fully understand all the possibilities offered by information technology. They need some food for their thoughts in order to imagine what the future situation might be like. This will lead towards the iterative type of design.

Bannon summarises his findings using following slogans:

- "From Product to Process in Research and Design"
- "From Individuals to Groups"
- "From the Laboratory to the Workplace"
- "From Novices to Experts"
- "From Analysis to Design"
- "From User-Centered to User-Involved Design"
- "From User Requirements Specifications to Iterative Design"

If one would like to find a common denominator for this list, it would perhaps be named as "better contextuality", because all of the directions discussed aim at taking some aspect of real-life use situations better into account. Beside active actors and contextuality, the third major new direction recognized by Bannon is the constructive relation between "users" and "systems": "In fact, it is often still the case that computer users need to make some modifications to the system in various ways, tailoring the system before it is truly usable. So in a very real sense *users are designers* as well" (Bannon, 1991b, s. 29).

What is behind this kind of change and development? Is there a larger pattern where it would fit?

4. Enlarging research object

Jonathan Grudin has written an interesting paper titled: *The Computer Reaches Out: The Historical Continuity of Interface Design*, for HCI'90 conference (Grudin, 1990). According to him, there has been a continuing, phasewise development "outwards" from the hardware: "...there is a continuity to the outward movement of the computer's interface to it's external environment, from hardware to software to increasingly higher-level cognitive capabilities and finally to social processes" (Grudin, 1990, p. 1). He considers that the phases or steps are not exclusive but they show more the relative importance of the corresponding problems of design and research at any time: "When we have solved the most pressing problems at one level - or can handle them adequately - human and computer resources are available to work on next level" (Grudin, 1990, p. 4). Grudin has recognized five phases or levels in the development: the interface at hardware, the interface at programming task, the interface at the

terminal, the interface at the interaction dialogue and, finally, the interface at the work setting. Grudin's view of the development is quite similar to those presented by A. Friedman in his influential book about the development history of whole computer systems (Friedman, 1989). Both of them see that the older problems do not become totally solved, but stay alive beside the newer, larger ones - only their relative importance diminishes gradually.

Grudin's this paper can be criticized because of its implicit "computer-centrism", but the idea to have interface defined at different, coexisting levels is very interesting, because it obviously can relieve some conceptual problems and confusions. Thus it is not surprising that the idea of reducing the confusion by looking at the interface from several perspectives or levels has been attractive to many researchers like (Bentley, Hughes, Randall, Rodden, Sawyer, Shapiro, et al., 1992) and gaining more and more popularity during the last years, e. g. (Booth, 1989; Clarke, 1986; Gaines & Shaw, 1986; Kammersgaard, 1988; Rasmussen, 1986; Smithson & Hirschheim, 1990; Stary, 1990; Weir, 1988). There are, however, some problems with these attempts. Although the use of different perspectives may help in clarifying different approaches to the interface, it does not necessarily help in relating them to each other because of the lack of any unifying background. Even in those cases where a hierarchical, layered model has been proposed (e. g. Clarke, 1986; Bentley, et al., 1992; Stary, 1990), the result is more *ad hoc*. Although Grudin does not attempt to develop a background framework in his classification paper, the connection of the levels to the historical development is certainly an important step to the right direction.

We have in (Kuutti & Bannon, 1991) continued this line of thinking by using the experience collected in Information Systems Research as a basis for our own levels of classification. In IS research there has namely been developed a certain consensus that three levels of description are necessary and sufficient to describe information systems, and because interfaces are a part of information systems, it might be possible to deal with them using the same classification. We have recognized the following three levels: a technical level, a conceptual level and a work process level. It must be admitted, however, that although the strong connection with the IS research tradition may give our classification some practical creditability, it is still suffering from the same problem than the other ones: lack of unifying theoretical background. In the paper we connected the growing importance of the "work process level" in HCI with changes in work practices themselves - with the movement from predetermined work sequences of tayloristically organized work towards flexibility and self-direction in "neotaylorized" work organization.

If we follow the IS tradition and accept the postulate of those three levels - the technical, the conceptual and the work process one - a hypothesis can be made that the problems and debates within HCI research discussed here are due to a change or enlargement of the research object of HCI from one "level" to another. The nature of this change is obviously a movement between the "conceptual" and "work process" levels: conceptually oriented "cognitive" HCI research is criticized in the debate because it does not take "work process" aspects properly into account.

Thus we have three broad "traditions" in HCI research: the "technical" one, having roots already in the old "knob-and-dial" ergonomics, concentrating human perceptive abilities and motor skills and corresponding features of technical devices¹, the "conceptual" one that has formed the information processing psychology-based mainstream of HCI research, and the

¹ It must be remembered that the publication of some journals recently actively publishing HCI research has started well before the "cognitive turn" in psychology, e. g. Human Factors and Int. Journal of Man-Machine Studies.

emerging new one searching new frameworks and theories in order to deal with the complexity.

What could the role of Activity Theory be in this situation?

5. Activity Theory: Some Key Ideas

Introduction

Both parts of the term "Activity Theory", used in English to refer to the Soviet-originated cultural-historical research tradition, are unfortunately slightly misleading, because the tradition is neither interested in "activities" in general² nor is it a "Theory" with a capital T – a fixed body of accurately defined statements³. Because the term has already become established in use, however, we just have to cope with it.

Activity Theory has long historical roots which are quite unfamiliar to most Anglo-American readers. The oldest background tradition — the 18th and 19th century classical German philosophy from Kant to Hegel — has remained distant because that tradition opposed the emerging (British) empiricism that was later to become the foundation of the mainstream Anglo-American scientific thought. The classical German philosophy emphasised both developmental and historical ideas and the active and constructive role of humans. Another root – also alien to many – consists of the writings of Marx and Engels, who elaborated the concept of activity further⁴, and the third source is the Soviet cultural-historical psychology, founded by Vygotski, Leontjev and Lurija⁵.

Although the background traditions of Activity Theory may be unfamiliar, some Anglo-American research traditions have been following similar venues of thought. Thus it is possible to recognize parallels between Activity Theory and e. g. directions like Dewey's pragmatism (see Tolman & Piekkola, 1989) and G. H. Mead's symbolic interactionism (see Star, forthcoming).

² The term "activity" does not carry the essential connotation "doing in order to transform something", like the corresponding German or Russian terms ("Tätigkeit" and "dejatel'nost")

³ The term can be used in two senses: either referring to the original Soviet tradition ((Leont'ev, 1978; Leontjev, 1981; Wertsch, 1981) or referring to the international, multivoiced community applying the original ideas and developing them further (for example, see (Engeström & Punamäki, forthcoming)). This paper is based mainly on the "Finnish" interpretation of original ideas, worked out by Y. Engeström and his co-workers ((Toikka, 1985), (Engeström, 1987))

⁴ The origins of the concept of activity lie in German idealistic philosophy, in which Kant, Fichte and Hegel emphasized the role of mental activity (Tätigkeit) in constituting the relationship between subject and object. This was nevertheless an idealistic-subjective interpretation. The concept of activity was brought into materialistic philosophy by Feuerbach, who emphasized the primary role of objective reality, but only as an object of contemplation. The activity concept of Marx was developed as "practical-critical" activity, the central aspect in activity being the transforming of material objects (gegenständliche Tätigkeit) ((Klaus & Buhr, 1987), pp. 1203-1207).

⁵ The original foundation of Activity Theory was laid by L. S. Vygotsky during the 1920s and early 1930s as a "cultural-historical" school of psychology. His work was continued by A. N. Leontjev and A. R. Lurija who developed his ideas further and started to use the term "activity". A good historical review of that development can be found in (Leontjev, 1989).

Activity Theory was first born within Soviet psychology, but today there is an emerging multidisciplinary and international community of scientific thought united by the central category of activity — a community reaching far beyond the original background⁶.

Broadly defined, Activity Theory is a philosophical and cross-disciplinary framework for studying different forms of human practices as development processes, both individual and social levels interlinked at the same time. In the following three of the key principles of Activity Theory are highlighted:

Activities as basic units of analysis.

Many psychological theories use human action as the unit of analysis. While this makes it relatively easy to design laboratory experiments, the use of isolated actions in analysing real-life situations outside a laboratory is much less fruitful. The reason for this is that actions are always situated into a context and they are impossible to understand without that context (e. g. (Suchman, 1987). The solution offered by Activity Theory is that a minimal meaningful context for individual actions must be included in the basic unit of analysis. This unit is called an activity. Because the context is included in the unit of analysis, the object of our research is always essentially collective, even if our main interest were in individual actions. "Activity is a nonadditive, molar unit of life for the material, corporeal subject" (Leont'ev, 1974, p. 10). An individual can and usually does participate in several activities at the same time. The concept of activity is elaborated further in the next section.

History and development.

Activities are not static or rigid unities but they and their elements are under continuous change and development and this development is not linear or straightforward but uneven and discontinuous. This means that activities have also each a history of their own. Remains of older phases of activities stay often embedded in them as they develop, and historical analysis of the development is often needed in order to understand the recent situation.

Artifacts and mediation.

An activity always contains various artifacts such as instruments, signs, procedures, machines, methods, laws, forms of work organization, etc. An essential feature of these artifacts is that they have a mediating role. Thus relations between elements of an activity are not direct but mediated: for example, instrument mediates between an actor and the object of doing; the object is seen and manipulated not "as such" but within the limitations set by the instrument (see e. g. Engeström, 1991b). Artifacts themselves have been created and transformed during the development of the activity itself and carry with them a particular culture — historical remains from that development. Because of the nature of artifacts, they should be never treated as "given". "The idea is that humans can control their own behaviour — not "from the inside", on the basis of biological urges, but "from the outside", using and creating artifacts. This perspective is not only optimistic concerning human self-determination. It is an invitation to serious study of artifacts as integral and inseparable components of human functioning." (Engeström, 1991a, p. 12.).

⁶Activity Theory has been found to be useful and flexible for the analysis of other disciplines as well, such as education, the social sciences, cultural research, anthropology, work science etc. (see e.g. (Hildebrand-Nilsson & Rückriem, 1988), (Engeström & Punamäki, forthcoming)). The activity theory "school" has just getting organized, the First International Congress on Activity Theory having been held in Berlin 1986, and the Second Congress in Lahti, Finland in 1990. From 1988 there has also been a journal - the Multidisciplinary Newsletter for Activity Theory.

The structure of an activity

An activity is a form of doing directed to *an object* and activities are distinguished from each other according to their objects. Transforming the object into *an outcome* motivates the existence of an activity. An object can be a material thing, but it can also be less tangible (like a plan) or totally intangible (like a common idea) as long as it can be shared for manipulation and transformation by the participants of the activity. It is possible that the object and motive themselves will undergo changes during the process of an activity; the object and motive will reveal themselves only in the process of doing. Mediation is carried out by introducing a third, intermediate term which carries with it the history of the relationship. Thus the (reciprocal) relationship between the subject or actor and the object of activity is mediated by a "tool" into which the historical development of the relationship between subject and object thus far is condensed. The "tool" is at the same time both enabling and limiting: it empowers the subject in the transformation process with the historically collected experience and skill "crystallized" to it but it also restricts the interaction to be from the perspective of that particular tool or instrument only - other potential features of object remain "invisible" to subject (Figure 1).

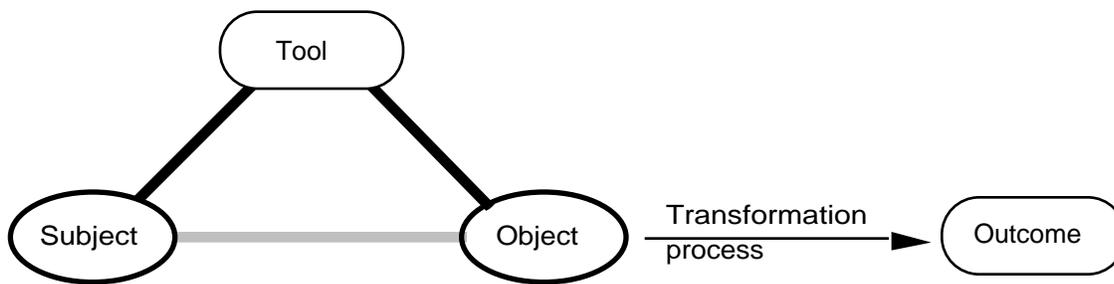


Figure 1: Mediated relationship at individual level

This structure is too simple to fulfil the needs of a consideration of the systemic relations between an individual and his environment in an activity, however, and thus a third main component, namely community (those who share the same object) has to be added. Two new relationships are then formed: subject-community and community-object. Both of them are also mediated and thus we have the following structure (Figure 2):

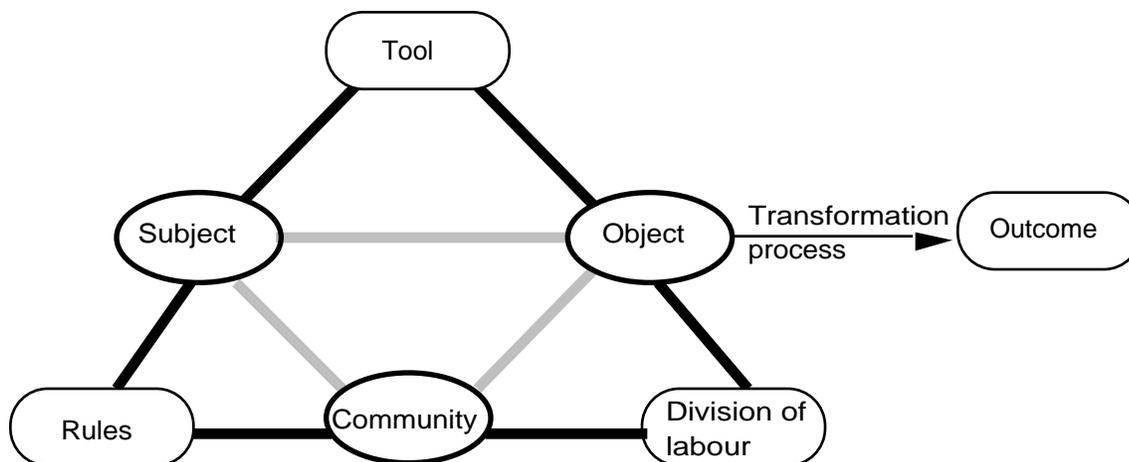


Figure 2: Basic structure of an activity

This systemic model — which is based on the conceptualization by Engeström (1987) — contains three mutual relationships between subject, object and community. (An activity is actually a systemic whole in the sense that all elements have a relationship to other elements, but

all those connections have not been presented in the picture because of sake of clarity). The relationship between subject and object is mediated by "tools", the relationship between subject and community is mediated by "rules" and the relationship between object and community is mediated by the "division of labour". These three classes should be understood rather broadly. A "tool" can be anything which is used in the transformation process, including both material tools and tools for thinking; "rules" cover both explicit and implicit norms, conventions and social relations within a community; "division of labour" refers to the explicit and implicit organization of a community as related to the transformation process of the object into the outcome, Each of the mediating terms is historically formed and open to further development.

An activity is the minimal meaningful context to understand individual actions. The famous example by Leontjev (1978) is about primitive hunters who in order to catch a game separate into two groups: catchers and bush-beaters frightening the game towards them. When compared with the motive of hunting – to catch the game to get food and clothing material – the actions of the bush-beaters are irrational; they can be understood only as a part of the larger system of the hunting activity.

Let us take a more contemporary example of an activity – a software team programming a system for a client. The object is the not-yet-ready system which should be transformed into a delivered, bug-free application. The team is the community sharing the object, perhaps joined by some representatives of the customer. There is a certain division of labour: between manager and his or her subordinates, between software developers and user representatives and between the team members. There is a set of rules covering what it is to be a member of this community. Part of these rules may be explicit – set by the laws, parent organization, or the team manager – but part of them is most certainly implicit, either as a part of the general working culture or developed locally during the time when the team has been working together. Some rules may be constructed for this particular project, for example how the user representatives of this particular customer shall be treated. In each step of the transformation process a different set of tools and instruments is used in the transformation process: analysis methods, computers, programming tools, walkthroughs, rules of thumb, etc. The collection of these tools has a history: it is a result of a process of cumulation and rejection at both company and team level and additions and deletions to it may occur during any project. Whatever the members of the team do during the project is shaped by the context of activity.

At the same time there is another activity where the object is the financial status of the software company and the community consists of team managers and their superiors. Every team manager has his or her own tools and tricks in order to keep the project within budget and profitable, and their superiors have their own. There is a certain division of labour and a certain set of rules – most certainly different from that within a team.

We can imagine a third activity where some of the team managers compete against each other for an available post as a department manager. The object "field" is the relative weight of capabilities and assets – either real or imagined – of each applicant in the eyes of the selection jury members. These assets can be transformed either by increasing one's own assets or diminishing those of others; each participating team manager has tools for that – excellent financial results from the current project, for example. Again, there is also a "division of labour", at least between applicants, those who do the selection and those who can impact the selection. And most certainly there is a certain set of explicit and implicit rules of what is correct behavior in the situation and what is not.

Thus real life situations always involve an intertwined and connected web of activities which can be distinguished according to their objects. Participation in connected activities having very different objects can cause tensions and distortions (e. g. the position of the team manager in the example above: bug-free delivery vs. excellent financial results). Psychologically, activity

theorists believe that participation in different activities is the major factor in creating consciousness and shaping personality.

Levels of an activity

Activities are longer-term formations and their objects cannot be transformed into outcomes at once, but through a process consisting often of several steps or phases. So there is a need for shorter-term processes: activities consist of *actions* or chains of actions, which in turn consist of *operations*, forming the following levels (Figure 3):

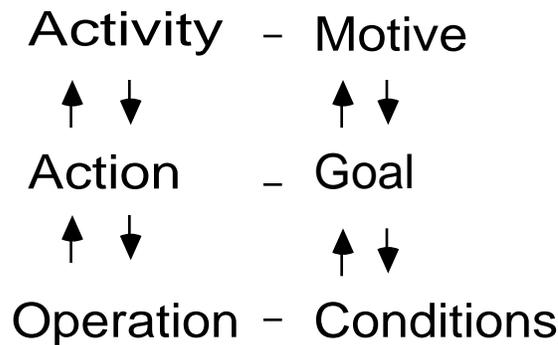


Figure 3: Hierarchical levels of an activity.

Activities are realized as individual and cooperative actions, and chains and networks of such actions, related to each other by the same overall object and motive. Participating in an activity is performing conscious *actions* which have an immediate, defined *goal*. The actions cannot really be understood, however, without a frame of reference created by the corresponding activity. One activity may be realized using different actions, depending on the situation: for example, the software development activity described above consists of different actions depending on how much actual code has to be produced and how much old code can be used, parts of application purchased from outside etc. On the other hand, one and the same action can belong to different activities, in which case the different motives of activities will cause the action to have a different *personal sense* for the subject in the context of each activity. For example, the action of reporting on the progress of the project in the previous example will have a different connotation if it belongs to the activity of internal project management than if it belongs to the activity of competing on promotion – even if the action and its other ingredients are exactly the same.

Before an action is performed in the real world, it is typically planned in the consciousness using a model. The better the model, the more successful the action. This phase is called *orientation*. Thus models and plans are not rigid and accurate descriptions of the execution steps but always uncomplete and tentative, *resources* in the sense of Suchman (1987). For their part, actions consist of chains of *operations*, which are well-defined routines used subconsciously as answers to *conditions* faced during the performing of the action. Initially each operation is an conscious action, consisting both the orientation and execution phases, a but when the corresponding model is good enough and the action has been practiced long enough, the orientation phase will fade and the action will be collapsed into an operation, which is much more fluent. At the same time a new action is created which will have broader scope and will contain the recently formed new operation as a subpart of itself. On the other hand, when conditions change, an operation can again “unfold” and return to the level of conscious action (so that it is not a conditioned reflex).

This action-operation dynamics and the *broadening scope of actions* is a fundamentally typical feature in human development. To become more skilled in something operations must be

developed so that one's scope of actions can become broader while the execution itself comes more fluent. A good example of action-operation dynamics is learning to use a manual gearbox when driving a car. At the beginning every step in the process (ease the gas pedal – push the clutch pedal – move the gear lever to a new position – release the clutch – give more gas again) is a conscious action that really needs planning, sequencing and decision; many times a hasty look at the gear lever is even necessary in order to move it. But soon these conscious actions start to transform into operations; the planning and decision-making will fade away, resulting a smooth "gear-changing action", far from the clumsiness of the initial attempts. Eventually, this gear-changing action will also become an operation in broader "corner-turning", "lane-changing" and "distance-maintaining" etc. actions and fade from the consciousness.

The border between action and activity is also blurred, and movements are possible to both directions:

“Thus an activity can lose its motive and become an action, and an action can become an operation when the goal changes. The motive of some activity may become the goal of an activity, as a result of which the latter is transformed into some integral activity. (...) The mobility of the constituents of activity is also manifested in the fact that each of them may become a part of a unit or, conversely, come to embrace previously relatively independent units (for example, some acts may be broken down into a series of successive acts, and, correspondingly, a goal may be broken down into subgoals).” (Davydov, Zinchenko, & Talyzina, 1983, p. 36).

The flexibility of the basic concepts makes them useful in describing development processes. On the other hand, it also means that it is in fact impossible to make a general classification of what an activity is, what an action is, etc. because the definition is totally dependent on what the subject, object etc. in a particular real situation are. Thus the following classification is not by any means exhaustive or, in the strict sense, even appropriate, but it does try to provide a first grasp of how the levels of the hierarchy could be realized in hypothetical, individual-level activities.

Activity level ↓ ↑	- Building a house	- Completing a software project	- Carrying out research into a topic
Action level ↓ ↑	- Fixing the roofing - Transporting bricks by truck	- Programming a module - Arranging a meeting	- Searching for references - Participating in a conference - Writing a report
Operation level	- Hammering - Changing gears when driving	- Using operating system commands - Selecting appropriate programming language constructs	- Using logical syllogisms - Selecting appropriate wording

Figure 4: Examples of activities, actions and operations.

As stated above, there are no firm borders: a software project may be an activity for the team members, but the executive manager of the software company may see each of the projects as actions within his or her real activity at the level of the firm.

One very important feature is that activities have a double nature: there is both an external and an internal "side" in every activity. The subject and the object of an activity are in a reciprocal relationship with each other: on one hand, the subject is transforming the object — on the other hand, the properties of the object penetrate into the subject and transform him or her. This is called *internalization*. In internalization

“...processes are subjected to a specific transformation: they are generalized, verbalized, abbreviated, and, most importantly, become susceptible of further development which exceeds the possibility of external activity”. (Leont’ev, 1974, p. 18).

Activity Theory does not accept a dualistic conception of a isolated, independent "mind": the internal "side" of an activity cannot exist without the external one. A person’s internal activity assimilates the experience of humanity in the form in which it manifests itself in the corresponding external activity.

"Cognitive processes (...) are not independent and unchanging 'abilities' or 'functions of human consciousness; they are processes occurring in concrete, practical activity and are formed within the limits of this activity" (A. R. Luria, cited in Stetsenko, 1993, p. 43).

“It means that a person’s mental processes acquire a structure necessarily linked to sociohistorically formed means and modes, which are transmitted to him by other people through teamwork and social intercourse.” (Leont’ev, 1974, p. 19).

Although the triangle model presented above may look somewhat rigid, it is only for the sake of representational simplicity and convenience. It is important to remember that Activity Theory does not consider activities as "given" or static entities, but dynamic ones: activities are always changing and developing. This development is taking place at all levels: new operations are formed from previous actions when participants' skills are increasing; correspondingly, at the level of actions the scope of new actions is enlarging -- but also totally new actions are invented, experimented and adapted as responses to new situations or possibilities encountered in the process of transforming the object; finally, at the level of activity the object/motive itself (and the whole structure of activity related to it) is reflected, questioned and perhaps adapted, reacting to larger changes and other activities.

Because activities are not isolated units but more like nodes in crossing hierarchies and networks, they are influenced by other activities and other changes in their environment. External influences change some elements of activities causing imbalances between them. Activity Theory uses the term *contradiction* indicating an unfit within elements, between them, between different activities or different development phases of a same activity. Contradictions manifest themselves as problems, ruptures, breakdowns, clashes, etc. Activity Theory sees contradictions as sources of development; real activities are practically always in the process of working through some of such contradictions.

What, then, is the relationship between activities and information technology? Answer to the question is not easy or straightforward, because information technology can support and penetrate activities at all of the above levels. First of all, a considerable share of all technology in use has been born and still exists for automating former human operations. According to (Leont’ev, 1978), in principle all operations can be automated: an automatic transmission of a car does exactly that to human gear-changing operations. Information technology is no exception: the major driving force in the development of first computers was the explicit need to automate human calculating operations, and one of the forces behind the expansion of information technology has been the need to automate administrative data manipulation operations. By automating and substituting human operations information technology can

become a part of an activity and vastly expand the scope of actions available to the participants. Automation is the oldest and perhaps best understood way to support activities, but it is not the only way. Information technology can also support actions, and this can happen in various ways. First, information technology can serve as a tool in manipulative and transformative actions directed to an object or to a part of it. A common form of this are different editors and other symbol-manipulation tools: spreadsheets, drawing, painting, etc.

Not only manipulative or transformative actions can be supported: information technology can for example help also in actions that are directed towards sense-making. (Zuboff, 1988) uses the term "informatate" in characterizing the situation, where information technology provides a "window" to look at the object of work in order to understand it better. In a way, managers have been "informed" from the first rapport ever produced by a system, but an enormous variety of other activities could in principle be supported in this way as well. In Oulu we have for example been studying how a novice could be helped to "learn the ropes" more easily by making some elements of a particular activity more visible through information technology (Favorin & Kuutti, 1994; Kuutti, 1993). Another class of potential actions to be supported are communicative actions between participants. These are also not directed towards manipulating or transforming the object but making the activity "run": coordinating, negotiating, etc. about object/motive, about structure of activity, about actions, etc.

Finally, at the activity level information technology can form the matrix of activities: it can be the principal enabler for an activity. At least two different possibilities can be identified. First, information technology may enable that an activity can be practically possible and feasible, for example by linking the participants by a network or system. Secondly, information technology may enable an activity to have an object that would otherwise been impossible to grasp: in (Kuutti & Virkkunen, 1994) we discuss about a case where only a computerized "organization memory" enabled work health inspectors to grasp and make new, much broader problems to the object of their work activity.

The support possibilities can be illustrated by using the following classification (Figure 5), where the internal side of activities is (somewhat rudely) compressed under the "actor" heading:

	OPERATION-LEVEL SUPPORT	ACTION-LEVEL SUPPORT	ACTIVITY-LEVEL SUPPORT
TOOL, INSTRUMENT	- automating routines	- supporting transformative and manipulative actions - making tools and procedures visible and comprehensible	- enabling the automation of a new routine or construction of a new tool
OBJECT	- providing data about an object	- making an object manipulable	- enabling something to become a common object
ACTOR	- triggering pre-determined responses	- supporting sense-making actions within an activity	- supporting learning and reflection with respect to the whole object and activity
RULES	- embedding and imposing a certain set of rules	- making the set of rules visible and comprehensible	- enabling the negotiation of new rules

COMMUNITY	- creating an implicit community by linking work tasks of several people together	- supporting communicative actions - making the network of actors visible	- enabling the formation of a new community
DIVISION OF LABOUR	- embedding and imposing a certain division of labour	- making the work organization visible and comprehensible	- enabling the reorganization of the division of labour

Figure 5. A classification of potential ways of supporting activities by information technology.

This classification does not aim to be a complete explication of the relationships between information technology and an activity, but it attempts to illustrate the wide scope and variety of these relations. The classification is also somewhat artificial, because activities are systemic wholes and it is in fact impossible to delineate accurately different types in practice. For example, it is no wonder that the support types classified as action-level support in the tool area and in the object area overlap, because tools are defined to be the means of interaction between an actor and the object. Also "supporting sense-making" overlaps naturally with all instances of "making visible" in the same column.

It is interesting to notify that the support given to work activities by traditional information systems seems to match nicely with the first column; practically any such system is supporting the full range of potential types. It indicates that in the area of work automation we have already reached a certain level of sophistication, and those types of support are not by any means less important to work activities than more "advanced" or complicated ones. But the further we go from left to right in the classification, the more sparse are the systems designed for give a particular type of support and the bigger are the challenges of HCI design.

6. The position and possibilities of Activity Theory

When looking the complexity of the field as sketched in the previous section, it is easy to understand why the success of HCI has been so limited. Even from this overall perspective three broad classes of complexity have been recognised: the levels of actions to be supported, dynamisms inherent to all levels and a wide variety of potential support types. Against this background the "slice" covered by the mainstream HCI research is narrow indeed covering best the area of error-free execution of predetermined sequences of actions. Unfortunately, that is the area where HCI is not crucially needed: humans are so adaptive that eventually the error rate will fall onto acceptable level in most of the cases, whatever the interface may be. But when we move towards supporting work and sense-making in the work, the situation is drastically different: a bad interface can paralyze all efforts. The broadening of the scope in research and design is both important and difficult, as the parallel debates in different areas of design — in HCI, in CSCW and in Information Systems — are witnessing.

What could be the role and contribution of Activity Theory in these discussions? The essentials of Activity Theory and ways to use it in practice are elaborated in other papers of this book. In this overview I would like to emphasize three perspectives:

1) Multi-levelness.

By using Activity Theory it is in principle possible to discuss on issues belonging to different levels within at least to some extent integrated framework (Figure 6). Although that is certainly a major task, it is worth trying in order to relieve the ubiquitous fragmentation of the field.

HCI research/ design object area	Background theory	Corresponding Activity Theory research objects
"Contextual interaction": situatedness, active actors, constructivity	"Enriched infor- mation processing psychology" or multidisciplinary approach: studying social contexts	Activities giving context to actions and consisting of them
Enlargement in progress		
Conceptual interaction	Information processing psychology: studying mental models	Conscious actions containing orientation with mental models and chains of operations
Physical/technical interaction	Behaviorism: sensory, perceptual, movement coordination studies	Internalized and automatic operations, triggered by suitable conditions in situation

Figure 6. Activity Theory areas corresponding the defined levels of research objects.

2) Studying interaction embedded in social context.

The question of context and sense-making in contexts has recently risen into the focus of research, like illustrated in earlier sections. Activity Theory and the concept of activity seem to be particularly suitable and rich to be used as the starting point in studying contextually embedded interactions. It contains many features, like the recognition of actors, mediation, historicity, constructivity, dynamics etc. considered essential in the recent discussions.

3) Dealing with the dynamics and development.

In the previous section dynamism and development in several levels was recognized to be a fundamental characteristics of activities. Dealing with this dynamism has been largely neglected in HCI, however. Little has been learnt how the formation of new operations, sense-making and creation of new actions, or, ultimately, reconfiguring whole activities could be supported by information technology. One reason for this has clearly been the lack of frameworks and theories capable to deal with developmental and dynamical features of human practices. In this respect, Activity Theory offers a very promising venue of thought, because the ideas of change and development are fundamental to it. In this paper it is not

possible to cover the whole field of possibilities, but just to highlight one corner where benefits might be gained rather rapidly — the potential of utilizing action-operation dynamics in computer interfaces.

Despite the fundamental nature of action-operation dynamics in formation of all kinds of skilled practices, the supporting of it has largely been neglected in interface research and development. This is emphasised by the fact that in principle computers are very suitable in automating operations further. In fact, it is quite difficult to find a good example where the dynamics has been properly supported and a "smooth" formation of operations from older actions and the broadening scope of new actions would have been achieved. It is true that many programs have included different "shortcuts" to be used by more experienced users. These do not qualify as a support for action-operation dynamics, however, because usually they are totally different from the original command and form thus a new learning task instead of a collapse of a former action into an operation. It is also true that after a certain – relatively high – level of competence the broadening scope of actions by combining old operations can be to some extent supported by a powerful operating system such as UNIX with its command files, pipes and filters and maybe a large part of the popularity of it could be connected to this feature, but again, there is no "natural path" where it would occur almost automatically with increasing experience of use.

To support the dynamics properly, it is necessary that the orientation phase of an action can be dropped, but that something from the old action remains as a feedback in order to trigger the next possible operation. Luckily, there is a nice example simple enough to be described here: well-known "type-ahead" menus (described e. g. Shneiderman, 1992, 119-120). A type-ahead menu is a chain- or tree-organized menu with a input buffer into which a user can write his or her selection without having to wait for the menus themselves to appear. When the user knows beforehand all the selections he or she will make when going through the chain or tree of menus, they can be written together as one command in the beginning. Shneiderman gives us the following example:

"To users of a photo library search system that offered menus with type-ahead, a color slide portrait quickly become known as a CSP and a black and white print of a landscape became known as a BPL. These mnemonics come to be membered and chunked as a single concept" (Shneiderman, 1992, p.120).

What he presents is a nice example of action-operation dynamics. A whole chain of former actions with a full orientation phase (look at the menu and find the option to be selected) has collapsed into one single action that has a considerably larger scope than the pieces had. And it is easy to return back to the original actions, because they stay also permanently on the background.

According to Activity Theory, formation of operations from actions is ubiquitous. This hints that the action-operation dynamics should be a common feature of all computer programs. This result raises immediately a series of interesting questions: Because supporting the dynamics is not impossible — why it is so rare? Can this be done in other programs as well? What kind of use situations this strategy might prove itself successful? Can a similar effect be realizable in a graphical interface? Could it be possible to be done over several successive levels, so that an action that has already been formed by collapsing several actions into operations could be collapsed again in the formation of an even more powerful action? Starting to find answers to questions like this and to experiment with realization possibilities might open a new, largely untrodden path for HCI research and design, not easy, but certainly worth of pursuing.

When trying to cope with the interface design problem in all its complexity it would be of enormous help if there were a discipline studying from the design perspective the problem of

"how artifacts are used and utilized in individual and cooperative work" in general, not restricting its scope to computer systems only. Many of the fundamental questions in HCI are not unique but common to a broader class of artifacts. Unfortunately, such a discipline does not exist, but if there will be a shift in emphasis from automating work towards supporting it, that general problem will be difficult to avoid for long. Perhaps it is a sort of accident – due to on one hand the "opaqueness" of computer systems and on the other hand the necessity to accurately formulate and formalize whatever is put into them – that just HCI/CSCW research and design has been the first to formulate and attack these problems. As pioneers of the field our success has been somewhat limited. There is no reason to be ashamed or depressed, however: I believe that we should instead be proud of being in the forefront and go ahead — because there is no risk to become too proud: the field will teach us all the humbleness we will ever need...

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