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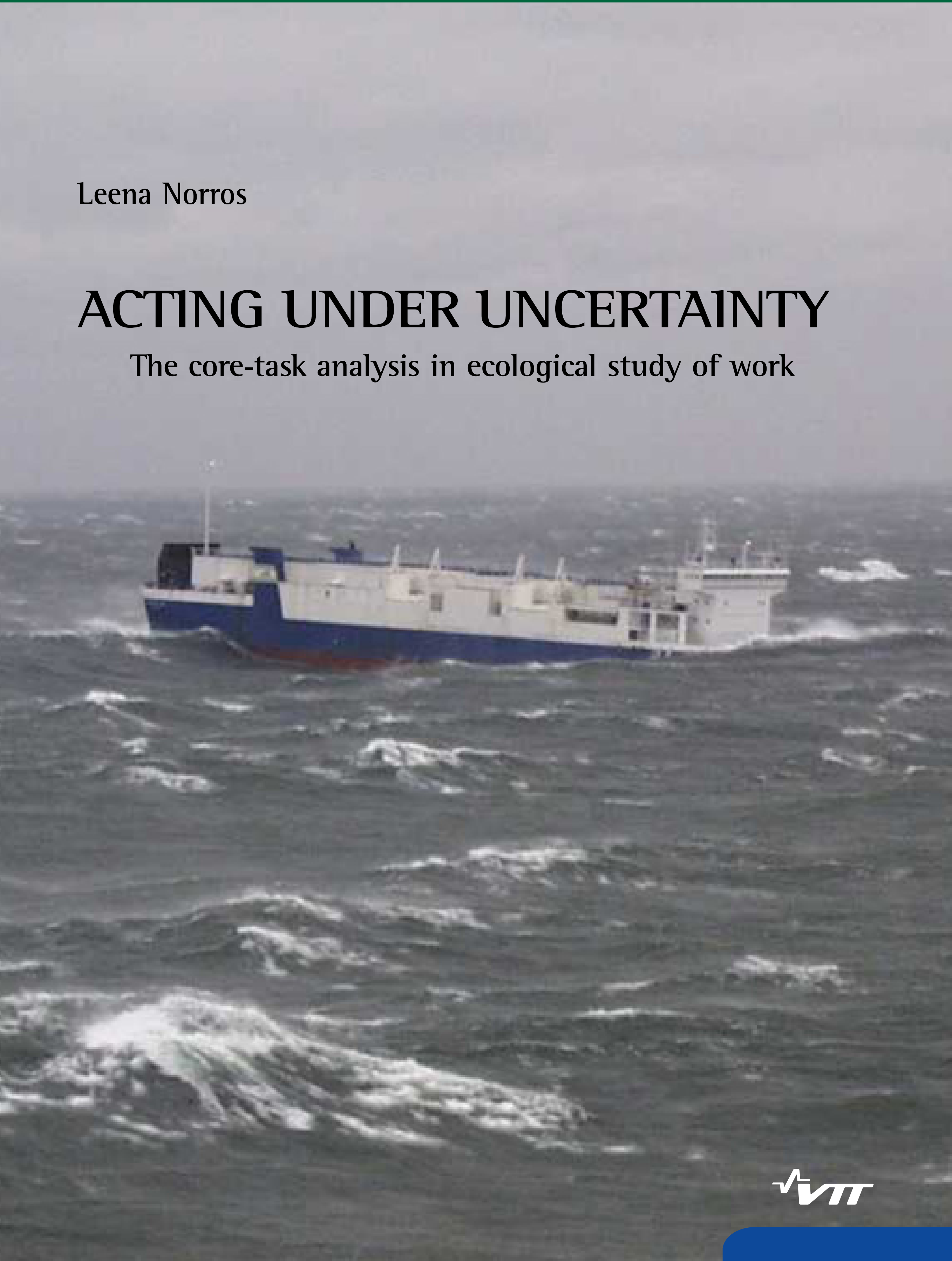
Leena Norros

ACTING UNDER UNCERTAINTY

The core-task analysis in ecological study of work



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Abstract

This book describes the emergence of a new method, the Core-Task Analysis (CTA), to analyse complex work in risky environments. The notion "core-task" denotes the objectives and the outcome-critical content of work, which should be taken into account by the actors in everyday task performance. The orientation to the core task characterises work practices and culture.

CTA adopts a systemic notion of human activity. Situated actions are conceived from an ecological, human-environment interaction perspective. The CTA methodology integrates several theoretical approaches. It exploits ideas of the cultural-historical theory of activity and the functionally oriented cognitive task analysis tradition, and it also borrows the pragmatist concept of habit for the analysis of practice. These approaches share a systemic notion of human activity and conceive action from an ecological, human-environment interaction perspective. Explaining actions from the point of view of their meanings characterises these approaches and the CTA-methodology. The CTA can be used in analysis, evaluation and development of work practices and culture, and it provides a framework for interdisciplinary studies of high-technology work.

The method was developed in studies of work in four technologically highly mediated work domains. These are flexible manufacturing, nuclear power plant operations, anaesthesia and navigation of large ships. Furthermore, the book reports empirical results concerning the nature of decision making and action under dynamic, complex and uncertain environments, and comprehends habits that might explain the observed differences in actual situational courses of action. The interpretativeness or reactiveness of habits of action is the central dimension that characterises the situated appropriateness of actions, while the core-task orientation defines contextual coherence of actions. The book also provides evidence of the deficiency of the notion of a linear development of expertise as a function of experience. It is argued that, rather, depending on peoples' orientation to work and on their habits of action, at least two different development perspectives emerge, which were labelled the trajectory of reflective expertise and that of confirmative expertise. In the final chapter the method is discussed in the context of the pragmatist conceptions of adaptive behaviour and learning. The book winds up by introducing preliminary thoughts of the use of the Core-task Analysis as a tool in managing high-reliability organisations.

Foreword

This book describes the emergence of a new method to analyse complex work in risky environments. Cognitive ergonomics, the research approach that focuses on human factors and organisational issues that arise in these environments, was practically non-existent in Finland when this work began in the early 1980s. One reason to this may be that, as in many other countries, aviation industry did not provide any significant incentives to tackle human factors issues in the design or operations. Yet, the exploitation of information technologies and the resulting increase of automation in industrial processes and transportation systems did create a need to understand and support human operators' work activities in these highly demanding contexts.

The emerging need for comprehending human-technology interaction was identified by far-sighted system engineers at the Technical Research Centre of Finland (VTT), especially by Björn Wahlström, and, on their initiative, research in this field was started, first on the nuclear power plant domain. The influence of the international research on the field was transmitted to VTT over joint Nordic research projects on nuclear safety. Jens Rasmussen and his younger colleagues Erik Hollnagel and Morten Lind served as an inspiring model for our emerging tradition. It was fascinating to note that my background in Winfried Hacker's action regulation school in Dresden communicated easily with these influences. The third and very significant influence in the development of our approach came from my cooperation with an interdisciplinary group of young scientists who drew on the Russian cultural-historical theory of activity. This cooperation, within which Yrjö Engeström was the leading figure, generated the tradition that has been labelled the developmental work research.

This book is a description of our efforts at VTT to work on theoretical and methodological issues while being involved in applied research projects. Our persistent aim was to develop a research approach in cognitive engineering that would, in an appropriate way, promote the solving of practical problems of work activity that we found both societally important and scientifically interesting. In this volume, it is my pleasure to make explicit the emergence of the methodology, the Core-Task Analysis, and to describe its theoretical underpinnings.

The work that I describe was not accomplished alone but, instead, it was a collaborative effort that consisted of scientific discussions, cooperative projects and shared intensive empirical work with many colleagues at VTT, in Finland and also internationally.

The most important collaborators in the development of the approach were Kristiina Hukki, Kari Toikka, Ulla-Maija Klemola and Maaria Nuutinen. Pia Oedewald, Teemu Reiman and Paula Savioja have made important elaborations to the method and opened new perspectives of application. Ari Kautto, Raimo Hyötyläinen, Risto Kuivanen, Lasse Reiman, Markku Malinen, Hannu Paunonen, Kari Laakso, Jan-Erik Holmberg, Pekka Pyy, Urho Pulkkinen, Rauno Heinonen, Antti Haapio, Martti Heikkilä and Kari Larjo, all engineering scientists or domain experts of different industrial fields, have considerably influenced the development of the approach by interacting with us over many years in an interdisciplinary discussion and work. Anneli Leppänen, Yrjö Engeström, Ritva Engeström, Marja-Liisa Kakkuri-Knuuttila,

late Renan Samurçay, Janine Rogalski, Nick Boreham, Jean-Michel Hoc, Pascal Beguin, Gene Rochlin, Babette Fahlbruch and Bernhard Wilpert have supported my work by knowledgeable opinions and comments in numerous discussions. It has also been my privilege to have been able to enjoy of the learned ideas and inspiring company of prominent advocates of cognitive ergonomics and work psychology like Lisanne Bainbridge, Veronique DeKeyser, Jack Leplat and James Reason. I express my deep gratitude to you all.

I want to express my thanks to the Finnish Work Environment Fund for financial support that enabled me a leave of absence. VTT industrial Systems contributed by freeing me from other duties for a number of months during which I was provided a work place and a fruitful research atmosphere at the Institute of Activity Theory and Developmental Work Research at the University of Helsinki. Technical University of Berlin supported my work significantly by inviting me to visit the Research Centre of System Safety during the preparation of the manuscript.

Michael Bailey deserves special thanks for correcting the English of the manuscript and for his witty elaboration of the usage of this language.

My final thanks go to my husband Ilkka Norros. Without his respect for this time-consuming work and insightful comments on the problems in which I was involved this book would never have appeared.

Contents

INTRODUCTION

1. Making sense in modern work

This book is an attempt to understand modern working activity and how people make sense of the dynamic, uncertain and complex environment of which they have only incomplete and contradictory knowledge. That people indeed do have knowledge of the environment is evidenced by the fact that they are able to act in it. The central questions posed in this book thus relate to the problems of the nature of knowledge and its relationship to practice, which are, of course, fundamental problems of philosophy. Therefore, one who is not a knowledgeable member of the philosophical community may hesitate to tackle them. The book explains why I have not been able to circumvent these questions and how I have approached them empirically, from an extra-philosophical point of view. There are two parallel discussions of work with which the present book may be linked. The first takes a decision making and cognitive engineering point of view and focuses on the analysis and design of human-machine interactions. The other discussion orients towards understanding working activity rather as a social phenomenon and focuses especially on the explanation of the dynamic construction of action in situations. The intention is to draw connections between these two discussions by presenting examples of empirical studies in high technology working processes, providing the bases for a new generic methodology for the study of work practices, the Core-Task Analysis (CTA).

When we in this book talk about the human environment we restrict the term to mean the working environment and an object of productive activity. We shall study work from a dynamic point of view as the construction of action in active engagement with the constituents of the environment. Thus, actions are seen as mutually shaped through the possibilities and constraints in the environment, and the learned tendencies or habits of the actors. This gives a reason to describe the methodology as an ecological approach. Work is a deliberately social activity that requires communication and the formation of a shared conception of its object and outcomes. Therefore it lends itself to an empirical study of constructing meaningful relationships with the environment more readily than some other, more private spheres of activity. For this reason the study of work may contribute to the understanding of the nature of human conduct and knowledge, and concretise and verify philosophical conceptions of these difficult topics.

1.1 Information technologically mediated work

In her book "In the age of the Smart Machine" Zuboff (1988) analysed the changes in work in the 1980s. Her predictions concerning the future development of work were rather accurate. Thus, the distinction she made between the two roles of information technology as both automating and potentially also increasing the information content of work has been important for the understanding of the problems of work in the information society. Whereas the substitution of human action by automation is the more evident benefit of information technology, exploitation of the informative and communicative potential of the new technology has turned out to be even more decisive for the development of work and expertise, as Zuboff assumed.

When acting in an uncertain environment human actors make judgements, i.e. they "are able to make considered decisions or to come to a sensible conclusion" (Pearsall

1998) with regard to their environment. Typical of judgements is that inferences about the state of the environment are made on the basis of distal cues that denote the phenomena of the environment. In this sense the cues provide a mediated relationship to the environment. Relying on experience, human actors intuitively make adequate inferences and actions based on only relative few cues of the object. In a traditional and slowly changing environment the features of the environment may be utilised in the human-environment interaction in an unproblematic way (Gibson 1979, Norman 1998).

The possibilities provided by information technology to measure the object and to connect, compute, represent, copy and transform information about it, challenge the actor's interaction with the object. Through its informing potentials information technology may open up new, earlier non-perceivable views of the object. Furthermore, the object is represented in the form of numbers or other symbols, whereas at the same time, the physical features of the objects may turn into shadow. As a consequence the object becomes physically more remote from the actor, while, however, information technology offers tools to intrude deeper into the object. The mediatedness of the interaction with the environment thereby increases.

The presently acute problems in the design of usable artefacts and human-machine interfaces are generic consequences of the mediatedness of working processes. The difficulties in the creation of new possibilities for constituting appropriate interaction with the world express themselves in both the operational and co-operational aspects of work. Wide exploitation of the technically already available intelligent and multimodal interface technologies is hindered by the problems that arise in the formation of meaningful and functional practices in their use. The possibilities to embed information technical solutions in the everyday environment is another feature of technology that challenges the design of products. Therefore, as Zuboff predicted, making use of the informative potential of information technology increases the demands on creation of new meaningful affordances for the mastery of interaction with the environment. (Zuboff 1988)

Increased technological mediatedness of working processes also creates the need to possess formal knowledge of the behaviour of the processes and conceptual handling of the relevant phenomena. This puts demands on the basic and professional training of the personnel. Thus, for example Leppänen has shown in her extensive studies in the paper and pulp industry that the conceptual mastery of even the main phenomena and critical parameters of the paper making process is notably deficient among experienced operators (Leppänen 2001). Importantly, she also showed that a training process building upon co-operative conceptual modeling of the work process has a great effect on the improvement of the operators' conceptual mastery of the process. The operators also made many suggestions for improvement of the process. The managers of the paper mills report marked enhancement in the quality of production and economical results after implementing these training programs, and recently such effects could be verified in a study that calculated economical gains of training investments in a case plant (Seppänen 2003). These results indicate an experience-based potential of the operators to participate in a conceptualisation and modeling of their work. The reported effects on productivity point out that the conceptual mastery of functionally significant phenomena and dynamic interactions of the process also become operational in action.

The information technological and conceptual mediatedness of the interaction with the environment is connected with changes in the social structuring of actions. As working processes become more extensive and the diversity of specialised skills and knowledge required in their mastery increases the conceptually articulated co-operation and communication demands also tend to become greater. The changes in work and working life today relate to the virtual nature of objects, the mobility of the actors and, enhanced networking of work. These changes appear to create difficulties for people in orienting and building up their expertise. For example comprehending one's position in the working community, formation of professional pride and identity, and acquisition of a sense of mastery of the job, have become less straightforward and less intuitive compared with the situation in traditional working environments and professional structures (Heiskanen 1999).

Developing understanding of interpretative processes

Understanding people's ability to make sense in uncertain environments has been our central research interest over many years. The adoption of the concepts of judgement or diagnostic judgement expresses our initial theoretical affinity with the traditional decision-making approaches. These are rationally oriented and emphasise the formal-objective features of the environment in the comprehending of the judgement process. In our studies on real-life process-control work we broadened the use of the concept of judgement and attempted to find philosophical justification for our understanding of the generic structure of judgement. We operationalised judgement as a combination of diagnostic and operational acts in constructing an interpretation of the situation. The notion of "interpretation" refers to the "act of explaining the meaning of something" (Pearsall 1998). Judgement can be conceived to be one expression of an interpretative act.

The content of the interpretation was analysed from the point of view of its appropriateness for the intended results of action. Drawing on Leont'ev, the process of interpretation was assumed to be regulated through orientation, a personal definition of the goal of action expressing a person's stance with relation to the object of activity and its societal meaning (Leont'ev 1978). Later, as we became acquainted with the ethnomethodological approach, the subjective and constructive aspects were emphasized in conceiving judgement. Our subsequent familiarisation with the pragmatist-oriented conceptions of action supported the emphasis on the operational and practical aspect of judgement (Dewey 1999).

Most importantly, however, the pragmatist approach introduced the idea of understanding the embodied and practical interaction with the world from the point of view of formation of meaning relationships (Peirce 1998b). In this context the concept of interpretation gained a deeper philosophical significance. As a feature of action, interpretativeness denotes the possibility of the human being to constitute generic relations with the world and thus to create continuity in action in a continuously changing environment. Habit is such a relationship and the way of establishing the interpretative continuity of behaviour. Habit conveys meaning and facilitates making sense of the world.

1.2 Towards an ecological study of work

One of the important approaches in contemporary research on action that has great relevance to our aspirations to study action and sense making in real situations, is the Naturalistic Decision Making approach (NDM) (Klein et al. 1993, Salas & Cannon-Bowers 1996, Zambok 1997). The attractiveness of this approach is, in the first place, due to the target domains that are typically studied by its proponents. These are dynamic technologically mediated human-environment-systems, the same that we have been involved with in our work. Furthermore, the NDM-community identifies the need for re-interpreting the traditional decision-making paradigm and seeks links with the study of action. Due to its background in decision-making research the NDM approach has a strong tradition in analysing ways of coping with uncertainty. Interpretative acts, mainly judgement processes, are thus the key interest of the approach.

The methodological challenges faced by the NDM research may be elaborated by comparing this approach with the study of human error. Analysis of human errors in accidental events in various industries (De Keyser & Leonova 2001, Rasmussen 1986, Reason 1990, Woods 1994) can be considered as an earlier version of the naturalistic research on action in high technology work settings. These studies usually focus on actions and particular sequences of events that have led to accidents or other unwanted results. In the analyses of the events particular elements of the sequences may have been shown to fail. Sometimes these elements are human actions that, for some reason, have been committed in an erroneous way or have been omitted. The task of the investigators is to analyse the underlying mechanisms of the human failure. Different kinds of classifications are used in the analyses. As a result these studies provide us with information on the prevalence of different error types representing underlying psychological error mechanisms.

In contrast to the above, in the NDM approach the target is to understand the organisation of the course of action in demanding working situations, not the mechanism of failure as such. The proponents of the NDM research community share the basic assumption of the contextual determination of actions and defines the research object as action in naturalistic environment (Klein et al. 1993, Zambok 1997). The task is to find adequate ways for tracing the on-going behavioural and cognitive processes (Woods 1993). Therefore, instead of conceptualising action as reacting to objectively definable events that can be held as reference, it becomes necessary to understand the situation itself as constructed in the subject’s interaction with the features of the environment. The perspective should, then, be to study actions, and safety of high-reliability organisations as a dynamic non-event (Weick 2001, p. 335).

From the situated construction point of view it appears evident that the structure of action depends both on its context, denoting the material and the cultural circumstances of action, and the intentions of the agent. It is, however, difficult to handle intentional action in a contextual manner in empirical research. This difficulty also manifests itself in one of the most cited new methods within NDM, the concept of situation awareness (SA) (Endsley 1995a, Endsley 1995b). Whereas the general model of SA appears to acknowledge the ecological idea of *a human-environment* *interaction*, the operationalisation of this model in the research methods reveals an adherence to the standard information-processing metaphor. Situation awareness denotes the construction of an internal picture (Endsley 1995b), rather than the result-oriented organisation of the entire organism towards the environment in an intentional meaningful action. We interpret the problems as being related to two features of the theory. There seems to be no deliberate methodical attempt to define the characteristics of the environment in such terms that would allow conceiving the environment as a meaningful context for particular human action. Moreover, the intentions of the subjects as grounds for explaining action are deliberately excluded for the sake of the objectivity of the methodical procedures. Thus, NDM should make a methodological effort and take distance from too strong objectivism. This position corresponds with Lipshitz's line of argument (1997) in which he suggested consideration of the prevailing epistemic assumptions within the NDM regarding perception of the world and construction of knowledge.

A further change of perspective regarding the way we understand human behaviour in relation to its environment becomes necessary. In agreement with the NDM approach the object of research has in this book been defined as the human-environment interaction. We maintain however, that interaction should be understood as *activity of a unitary organism-environment system*. This definition of the object further qualifies our approach as an ecological approach (Gibson 1979, Järvilehto 1998a). This point of departure enables distancing from the widely held conception of behaviour as a linear process from stimulus to reaction, and opens up possibilities to describe action in more adaptive terms. The notion of adaptive situated construction of actions pre-requires acceptance of a certain subjectivity of our knowledge of the objectively existing world. Of course, the principle also concerns the investigators' own construction of their object of research. It requires distancing from an absolute objectivity conception of knowledge, according to which detachment from the object is a prerequisite for adequate knowledge. An alternative stance to objectivity comprehends the subjectivity of an agent as a prerequisite for his construction of the objective world in a communicative interaction with it (Megill 1997).

Because of its dependence on the context and its intentional nature, human action cannot be judged by external features and similarity only (Harré & Gillet 1994, Winch 1958). Even though it may be possible to identify regular behaviour patterns in human action man himself defines the logic according to which he may, or may not, take these regularities into account (Eskola 1999). Revealing this logic would open a way to understanding the dynamics of the formation of action from an ecological perspective.

The above reasoning leads us to what we consider as the methodological core of the approach developed in this book. In reference to Georg Henrik von Wright we would define the task in a psychological analysis of work as *clarifying what behaviour is a sign of, what does it mean* (von Wright 1998a, von Wright 1998b).

1.3 Integrating theories to form a new approach to analysis of work

An approach that coheres with the methodological principle of analysing action from the point of view of what it means is the anthropologically oriented analysis of cognition in real-life action. One of the most influential examples of this approach is the work of Lucy Suchman on the situated construction of action (Suchman 1987). Suchman's point of departure is the invention of ethnomethodology to take the common-sense reasoning of people as a topic of social science (Garfinkel 1967, Garfinkel & Sacks 1970). This idea has turned the research questions in the study of action up-side down. Instead of understanding action as an attempt to approximate scientifically definable adequate action in an objectively given world, the ethnomethodologically oriented researchers assume that our everyday social practices render the world publicly available and mutually intelligible (Suchman 1987). Important in the ethnomethodological tradition is the epistemic significance put on the situated actions in understanding the dynamic organisation of action. The focus is turned away from invariances between situations; instead the uniqueness of particular processes are systematically studied from the point of view of the meaning they render. The structure of action is seen as an emergent product of action rather than its foundation.

We became aware of the relevance of the ethnomethodological approach through practice. Hence, the feedback from our research subjects, the process operators, who participated in our human error studies, indicated that a more subject-centred methodology would be needed to give better justice to the operators' actions in complex environments.

When analysing action in real working processes, it also became evident that the physical and socio-organisational environment of the domains sets definite constraints and provides possibilities for action. For facilitating the consideration of the environment in explaining the organisation of action we have attempted to analyse the features of the environment and the circumstances of work in sufficient detail. However, when modeling the environment it is necessary to avoid the trap of taking the world as an independent and objectively given environment. The critical question then arises of how to describe the environment from the point of view of specifically human action. The concept of affordances was the solution developed by Gibson for this problem (Gibson 1977). We intuitively adopted this concept when we developed means to model the features of the domain and the task situations. The notion of affordance also appears in the writings of Jens Rasmussen. His work provided considerable inspiration for us and was of great help in the modeling of the environmental constraints (Rasmussen 1986, Rasmussen 1996).

A comprehensive work analysis methodology based on Rasmussen's work was suggested recently (Vicente 1999). In the cited book Vicente developed a formative approach for modeling work domains. This approach coheres well with our way of modeling the domain and the task situations. This provided a basis for incorporating Vicente's conception of formative modeling into our modeling method. Accomplishing the modeling of the environment as the domain of activity brings forth the need for interdisciplinary co-operation with investigators and other experts of the particular domain.

In formulating a solution where the environment is considered in concrete terms as the domain and context of actions and where, at the same time, a deterministic interpretation of the environment is avoided, we have drawn on the cultural-historical theory of activity (Leontjew 1973b, Vygotsky 1978). This theory provides explanations regarding the development of the psychological structure of human activity. Engeström developed the notion of activity system on the basis of the cultural-historical theory of activity. This notion puts forward a methodology for the analysis of the transformations in the activity from a systemic point of view (Engeström 1987). The internal contradictions of the system, and the tensions in the relationships with the surrounding activity systems are the sources of the dynamic change in the system. In our approach we make use of this frame when analysing the generic cultural-historically defined meaning of the possibilities and constraints that individual actors face in particular working processes.

The theory of Leont'ev has a further important contribution in the developing methodology. It offers convincing explanations concerning the connectedness of individual actions with the historically formed collective process of activity and its societal meanings. Personal action is related to the societal activity through the relationship that the person establishes between the situated goal of his actions and the motive of the societal activity in which the actions are embedded. This relationship is the personal sense of activity and expresses itself in a particular orientation to the object of activity as situated goal. The theory of Leont'ev advises to consider the subject's personal relationship to the actual environment as decisive for the dynamics of action.

However, the theory of Leont'ev does not make suggestions about how to study or operationalise the signification of the environmental conditions in corporeal behaviour. In order to elaborate the analysis of the meaning of behaviour, and to construct empirical ways to identify what are the reasons on which the subjects act, we have exploited the pragmatist notion of habit (Peirce 1998b). Through observation of actual operations and inquiring about their reasons it is possible to identify habits that are generic tendencies to act in particular environments. The existence of certain habits of action is inferred through the principle of behavioural inference of reasons suggested by von Wright (1998a). By adopting the above-described theoretical basis a new conceptually articulated way of analysing practices emerged.

1.4 The Core-Task Analysis

The above-described theoretical foundations constitute the conceptual basis for the Core-Task Analysis methodology (CTA). It is an approach for analysis of the development of work practices. By the concept of *"core-task"* we mean the shared objectives and the outcome-critical content of work that should be taken into account by the actors in their task performances for maintaining an appropriate interaction with the environment. The core task defines both possibilities for action and demands that must be fulfilled in all situations. (Norros 1998, Norros & Nuutinen 2002). Hence, the content of the core task defines what is meaningful in the particular work. In their work on organisational culture Oedewald and Reiman have elaborated the concept of core task by emphasising the shared nature of the core task (Oedewald &

Reiman 2003). The Core-Task Analysis methodology has three aims: It strives for defining what is the shared *meaning* and the outcome-critical *content* of a particular work and which demands it puts on action. It also provides an understanding of the dynamics of the *construction* of actions as it makes explicit whether and according to which logic the actor is taking into account these demands in real situations. Finally, it is a tool for *evaluating* working practices. Through reflecting the practices it is possible to facilitate their development and shape work culture.

The Core-Task Analysis method takes advantage of different kinds of empirical data. The analysis requires historical-documentary data of the development of the activity and of the design basis of the artefacts, descriptions of the working processes, norms, procedures, prescriptions, or descriptions that are used in regulating the activities, etc. The second major type of data is the actual-empirical data concerning working performances and peoples' conceptions of their work. This data includes observations of performance accompanied with process-tracing interviews, video-recordings of performance, theme interviews and recordings of especially designed group discussions.

The Core-Task Analysis is a theoretically founded scheme that guides inferences on data that may be prepared for use with the help of either qualitative or quantitative methods. The data is utilised in three theoretically founded phases of inference: *modeling of the work domain, analysis of habits*, and, *reason-based analysis of actions.* In the last phase the products of the two former phases are exploited for indicating good practices. As a result of accomplishing these inferences the habits of action and work orientations of the particular activity are defined. They constitute the descriptions of the working practices and cultures of the studied work domain. The inferences within the Core-Task Analysis scheme make use of a particular vocabulary that is formative and constraint-oriented in the case of analysing the work domain, and habit-theoretical and semiotic in the case of analysing actions.

The Core-Task Analysis method is an ecological research method in the sense that its point of departure is the notion of a *unitary human-environment system* (Järvilehto 1994, Järvilehto 1998a). It focuses on understanding the *dynamics of this system* and the *development* of the practitioners' actions as active engagement with the environment (Ingold 2000). A significant feature of the approach is the description of the environment and the human actor from the point of view of their potential for interaction, as affordances or intrinsic work constraints, and habits, respectively. Actual action is the realisation of these potentials in particular situations. Thus, the point is that by distinguishing meaning relationships in the realisation of action it is possible to understand what sense action makes for the actor and to identify the potential generic tendencies that are inherent in the action. Hence, we may make predictions of the appropriateness of performance in future situations.

Orienting to the core task promotes survival in the particular environment through facilitating the reproduction and development of the human-environment system. The result of the human-environment interaction is thus not seen to be restricted to the material product, but is rather interpreted to be growth of the possibilities of further interaction (Järvilehto 1994). This feature is a further qualifier of the methodology as an ecological approach.

There are different reasons why the core tasks cannot be taken for granted. The most significant reasons are that core tasks change and the content is not easy to comprehend. As a consequence, work practices may become inappropriate. The focusing of attention adequately in modern organisationally and technologically extremely mediated work can be facilitated through deliberate conceptual modeling of the core content of the work. Such modeling also helps to comprehend the possible changes in the core task during the frequent transformations of the activity systems. Directing attention towards the core task of work and to the development of practices requires collaborative reflection within the participants of the communities of practice. The idea of practice being formed and changed within communities of practice (Wenger 1998) links the study of the core task with the analyses and development of organisational cultures (Reiman & Norros 2002, Reiman & Oedewald 2002a). Development of culture needs analysis of practices and their underlying reasons which themselves contribute to culture.

1.5 The structure of this book

The aim of this book is to contribute to the theory of the situated organisation of action and to develop a method for the empirical analysis of work practices in dynamic, complex and uncertain environments. The methodology is called Core-Task Analysis (CTA). The central means for making the new methodology intelligible is to describe its development. We shall demonstrate the emergence of the method with the help of empirical studies of work that have been conducted in four technologically highly mediated work domains. These are flexible manufacturing, nuclear power plant operations, anaesthesia and navigation of large ships. The book is divided into four parts: Introduction, parts I and II and Conclusion. The contents of the chapters of the book are briefly introduced in the following.

In the second chapter *Work in dynamic, complex and uncertain environments* the object of research is defined. Our research object is the situated construction of action in complex dynamic and uncertain environments. We claim that the three general features of the modern working environments, dynamism (D), complexity (C) and uncertainty (U) each set particular demands for action in these environments. We shall use the term DCU-environments to emphasise the qualitative specificity and significance of each one of these features. The technological mediatedness of the work processes and the often strict reliability requirements add to the difficulty of balancing between the demands.

In the third chapter *Analysis of situated actions within activity systems* we conceptualise the research object, by exploiting three major theoretical sources, the system-theoretical modeling of domains, the cultural-historical theory of activity and the pragmatist conception of habit. The aim is to demonstrate that an integrative use of these theoretical sources is fruitful for the understanding of the construction of actions. The integration is justified because these three approaches share an ecological perspective. As a result, a new way to comprehend the development of work practices emerged.

The theoretical notions of the cultural-historical theory of activity are in our approach linked with the pragmatist theory of action. Thus, the notion of habit is adopted to complete the present theoretical apparatus of activity theory in the analysis of situated actions. The chapter is wound up with a model that demonstrates the relationships between the central concepts of the Core-Task Analysis, which focuses on the construction of situated action and aims at understanding the development of work practices.

In the subsequent chapters we shall explain the emergence of the Core-Task Analysis methodology. In the early stages of the development of the methodology two lines of research, the traditional decision-making approach on the one hand, and the cultural-historical theory of activity on the other, lived separate lives in our empirical studies. We shall start the elaboration of the approach in chapter four entitled *Disturbance orientation as an expression of expertise in modern manufacturing work.* The chapter describes a study within the domain of manufacturing. The invention in this study was to build up a conceptual method, with which we could identify differences in the operators' reactions to smaller disturbances and problems that occurred in the normal daily work. Disturbance orientations were taken to express different cognitive and motivational potentials for the development of both the system and personal mastery of the system, and they were considered as informative of the quality of operator's expertise.

In the fifth chapter, *Ways of acting in handling disturbances in nuclear power plant operations* the conceptualisation of diagnostic judgement as the qualification of expert action in DCU-environments is continued. Three experimental studies on the strategies of operators of nuclear-power-plants (NPP) for coping with difficult disturbance situations provide the empirical material for the inquiry. In these studies, the actual courses of action in simulated disturbance situations were considered in detail, and the decisions of the operating team in the different phases of the disturbance were scrutinised.

In this chapter we demonstrate the emergence of a method for identifying the extent to which people take into account the functional necessities of the domain in particular situations as reasons for their action. In the studies referred in this chapter the theoretical underpinnings of the notion of the way of acting were not yet sufficiently explicated.

In chapter six, *An ecological method for the analysis of situated action. A study in the anaesthetist's clinical practice* we shall first demonstrate the theoretical concepts that are used to comprehend the construction of situated action in the Core-Task Analysis method. An inference model of the CTA is then introduced. This model is subsequently used in empirical studies of work in natural situations. We shall review studies from two domains. First, in the sixth chapter, we shall develop new insights into the anaesthetists' practices. We analysed the practices with regard to coping with the dynamic course of one patient's anaesthesia process, and also from the perspective of the anaesthetists accumulating experience from one patient to the next, and we were able to distinguish distinct trajectories in the development of expertise. The described forms of practice could be interpreted as evidence of the pragmatist theoretical conceptions of action and learning. The interpretative habit of action demonstrates the notion of reflective habituality.

In analogy to the previous chapter, we shall in chapter seven *Habit of action as co-operatively and historically formed practice in the navigation of ships* demonstrate the use of the core-task-analysis method in the study of situated actions on the bridge of large ships in piloting situations. The special interest in this chapter is to elaborate the co-operative demands of the task and to analyse the prevailing co-operative habits of navigation. We also demonstrate the social historical determination of the currently distinguishable habits of piloting.

In the concluding chapter eight, *Interpretative practices for creating reflective expertise in organisations* we shall first demonstrate the reconstruction of the research object, modern technologically mediated work. The developed methodology brings together ideas of cognitive engineering and activity approaches with the pragmatist theory of habit with the aim of developing an ecological analysis of work. We shall also summarise the central empirical findings and, with their help, further conceptualise our understanding of reflective expertise. Then, finally, we return to the question that deals with choosing an appropriate strategy for the development of work in advanced technological domains.

Today, much interest is devoted to the development of the strategies of the management and the functioning of organisations, especially under the topic of knowledge management. The analyses and arguments are often rather general and they are made without direct reference to the actual working practices and their internal quality. The same general metaphors are used in all contexts.

The work research that is supposed to provide empirical results of the various working processes, to be taken into account by the managers of these organisations, does not even nearly succeed in its task. This may be due to dealing with "human and organisational factors" without connecting those phenomena to the operative content of particular working activities. We see this as an expression of insufficient ability and interest for constructing human work as an object of theoretical inquiry. Such an activity would provide methodological guidance that is needed to study work both in a context-dependent and holistic way. One of the strengths of the developmental work research (Engeström 1987) is the articulation of its own philosophical underpinnings and the continuous development of the theory intertwined with extended empirical research.

Moreover, it seems that there is still a rather strict separation and scarce communication between those disciplines that consider the physical, chemical and technical phenomena of work domains and those that focus on the human societal behaviour. This problem characterises both cognitive engineering and activity-oriented approaches. From an ecological viewpoint that emphasises the mutual determination of the human and the environment, the lack of interdisciplinary interaction does not make sense. Vicente makes an important contribution to solving this problem by proposing a constraint-oriented analysis of the work domain to be used in the design of working processes (Vicente 1999).

The reasons that Vicente gives for the constraint-oriented work analysis are convincing. A formative or predictive approach that he suggested is needed to facilitate adaptive actions that produce aimed results. In our conception the outcomes of action are understood in a further perspective, as new possibilities for action, not merely as its material products (Järvilehto 1998a). The concept of adaptation is thereby extended also to denote the potentials of human action that create these new possibilities. In order to reveal the existence of such potentials we need not only to approach the environmental affordances with the help of the formative approach. In addition there is a demand to describe how people take into account the affordances of the situation. The habit-centred analysis of actions included in the CTA provides a predictive vocabulary for analysis of the creative and adaptive potentials in the "end-users" actions.

The exploitation of the perspective of enhancing adaptability within organisations may be linked with the managers' insight of the core task of the organisation and the personnel. It could be suggested that focusing on the potentials of the reflective expertise and promoting the formation of personal knowledge and the development of comptencies would open up a prospective perspective for the information-intensive work in high-reliability organisations. I shall return to these assumptions after having introduced the Core-Task Analysis methodology and having provided insights into what people really do when producing toothed wheels, operating nuclear power plants, conducting anaesthesia or navigating ships.

PART I:
The object of research: The situated construction of actions and development of practices

2. Work in dynamic, complex and uncertain environments

The motive for the development of a new research methodology has emerged from our experiences in conducting psychological studies on decision-making and action in high technology working processes. These studies have mainly dealt with process control work. We shall begin this chapter by introducing features of process control as a working environment and by discussing problems that arise when attempting to understand real-life actions in such complex situations. We shall suggest that action should be understood as interactive functioning of a unitary human-environment system, which approach provides an ecological frame for the study of action. Then we shall move on to conceptualising the outcome-critical features of the environment. These features may be conceived as intrinsic constraints that put demands on skills, knowledge and collaboration. The intrinsic constraints are interpreted as affordances that require interpretation in action. The chapter will end by the formulation of three generic methodological principles for the research method under development, the Core-Task Analysis.

2.1 Process control as a work domain

Process control is a particular type of work characteristic to process industry. Examples of this type of industry are chemical and power plants, or paper and pulp processes. Process control work is also typical in transportation industries. Thus, working activities such as flying aeroplanes, air traffic control, or steering and navigating large ships may be cited. Finally, the anaesthetic treatment of patients, fighting forest fires, or controlling a rescue situation could also be treated as process control work. Typical to all these diverse activities is that the actors, who may generically be called process operators, continuously interact with an on-going dynamic phenomenon with the aim of maintaining an optimal functioning of the process for the purpose of producing a desired result. With the aid of modern information and communication technology (ICT), new man-made processes have been created through combining separate elements of manufacturing into holistic systems. Recently, ICT has enabled the construction of networks of production and business processes the operational mastery of which sets new types of process control demands.

Process control is an interesting domain for the study of action for at least two reasons. Firstly, these processes are extensive and contain a high concentration of energy, due to which they are often, safety critical and may cause risk not only to the workers but also to the surrounding communities and the environment. In the case of anaesthesia, for example, the risk is of course different, and is due to intervening with the vital functions of the patient. In these environments much effort has been invested to diminish the probability of unwanted events. However, should a non-probable event occur, it might cause a severe damage to the actors or to the environment. It is assumed that better understanding of the human behaviour involved in the control of these processes would promote safety.

Secondly, process control provides a laboratory for behavioural scientists and system engineers who are interested in the analysis of actions in dynamic situations. Features of decision making and action have been studied empirically in post-hoc accident investigations, in simulated working situations, and more recently increasingly in normal working environments. The resulting body of knowledge has potentially general relevance in explaining the construction of action in dynamic environments, and consequently the studies have high relevance for psychological theory building. However, it seems that the generic significance of the results acquired in the psychological studies on process control has not been sufficiently articulated. Study of process control is rather taken as application of psychological knowledge with the aim of improving safety within these industrial domains.

A classical account of process control was made by Edwards and Lees in their seminal book The Human Operator in Process Control (Edwards & Lees 1974). The work on process control was continued by some influential researchers in Europe and the USA (Bainbridge 1979, De Keyser et al. 1985, Duncan & Shepherd 1975, Leplat 1981, Leplat & Hoc 1981, Rouse 1981). As a result of this work the study of process control became a major topic of a research area called cognitive ergonomics or cognitive engineering. In the 1980s and 1990s cognitive engineering was conceptually greatly influenced by the work of Jens Rasmussen (e.g. Rasmussen 1986). He created an appealing model concerning the regulation of operator performance through a three-level processing regime. In recent years, process control research has been shaped by new traditions and trends in the study of work and action (Cellier et al. 1997, De Keyser & Leonova 2001, Roth 1997). Particularly the ethnomethodologically oriented research has provided new insights of process control action (Hutchins 1995). As a result, the study of process control is currently one line within a broader research area for which a generic label, the study of "cognitive systems in context", has been suggested (Hoffman & Woods 2000).

Industrial processes may be conceptualised as complex sociotechnical systems. This is the notion that for example Vicente (1999) uses in his book focusing on the analysis of process control work. His perspective is the design of the system, especially the information tools for its control. He defines the sociotechnical system simply as a "system composed of technical, psychological and social elements" (Vicente 1999, p. 9). Vicente conceives *complexity* as the characteristic feature of sociotechnical systems. With reference to authors like Perrow (1984) and Woods (1988), Vicente introduces a number of dimensions that could be seen to describe complexity. These dimensions are presented on the left-hand side of Table 1. The list of features is informative and the descriptions and examples given by the author under each dimension create a vivid picture of the complex sociotechnical systems as working environments.

A research tradition that has been labelled the naturalistic decision-making approach (NDM) also focuses on complex sociotechnical systems. Such a system is within this approach viewed from the decision-making perspective, as a natural decision-making environment. Focusing on real-life situations has consequences on the theoretical conceptualisation of decision making. Thus, the proponents of this approach state that the decision performance is dependent on the features of the task and the experience of the actor, both of which aspects are neglected in the classical decision-making approaches (Orasanu & Connolly 1993). The authors present an account of the significant features of the tasks in complex natural environments (Orasanu & Connolly 1993, pp. 7–10). A summary of the descriptions made by the NDM investigators may be found in the right-hand side of Table 1. The description is compatible with that offered by Vicente, as may be observed in Table 1.

Table 1. Two comparable characterisations of the features of complexity of sociotechnical systems as decision environments, and their consequences on action.

Dimensions of complexity in socio-technical Systems (Vicente 1999)	The central features of a complex naturalistic decision-making environment (Orasanu & Connolly 1993)
• Large problem spaces • Heterogeneous perspectives • Coupling • Distributed • Dynamic • Hazard • Disturbances • Uncertainty • Automation • Mediated interaction • Social	• Ill-structured problems • Shifting, ill-defined, competing goals • Action / feedback loops • Multiple players • Time stress • High stakes • Uncertain dynamic environments • Organizational goals and norms
=> Context Conditioned Variability, designing for adaptation	=> Ill-structured problems, decision making as action

The two above-mentioned descriptions both take complexity as the unifying feature of the sociotechnical system. Similar features are also conceived as the source of complexity, as the table indicates. The motivation to characterise the complexity features in these approaches is to enable conclusions regarding methods for the design of the systems or the adequacy of decision-making, respectively. The solution that Vicente (1999) proposes is the development of an *ecologically* oriented cognitive work analysis approach (CWA), within which the features of the work domain are the starting point of analysis. The feature that Vicente (1999) emphasises as the central determinant of complexity is uncertainty. In his analysis of open systems, which sociotechnical systems typically are, he, refers to earlier authors (Roth et al. 1987, Suchman 1987, Turvey et al. 1978), and draws attention to the uniqueness of each situation and to the different sets of contingencies they create. Moreover, he notes that if the same outcome has to be achieved on different occasions the actions that accomplish it must vary. He adopts the term context-conditioned variability for this phenomenon characterizing open systems (Vicente 1999). Further in the book he concludes that the philosophy behind his cognitive work analysis is precisely to "… uncover the requirements that will help workers be flexible, adaptive problem solvers. *CWA is all about designing for adaptation"* (p. 121).

The NDM community formulates the task of redefining the conception of decision making and developing a new *naturalistic* alternative. The proponents of NDM argue that, in contrast to the traditional decision-event model, in the naturalistic model decision making is conceived as embedded in a complex task setting. The decision problem is ill-structured and actions are demanded without the possibility for analytical comparison between decision options (Orasanu & Connolly 1993). The central methodological conclusion that concerns the object of research is that decision making is an on-going action rather than a singular choice (Brehmer 1990, Orasanu & Connolly 1993). In other words, the dynamic nature of the interaction with the environment is emphasised. The goal is to develop a set of models and methods for empirical study and to establish a community that could be identified through a common research practice (Klein 1997).

2.2 Process control as the functioning of a unitary human-environment system

We agree with the above-cited ideas of Vicente that in the analysis of process control we are dealing with a complex sociotechnical system. Likewise we appreciate the conclusion of the NDM approach that coping with sociotechnical systems should be understood as dynamic continuous action. We see, however, that the conceptualisation of the object of research should be developed even further. As a general solution for deepening the theoretical treatment of the sociotechnical system we suggest the adoption of the notion of *activity*. It is a conception that on a general level denotes the *functioning of a unitary human-environment system*. In the rest of this and in the next chapter we shall make an attempt to define our research object, the situated construction of action within an activity system. Action is seen as an emergent feature of the functioning of a human-environment system.

In the question of the nature of the human-environment system we adhere to the approach proposed by Järvilehto in his theory of the organism-environment system (Järvilehto 1994, Järvilehto 1998a, Järvilehto 1998b, Järvilehto 1999, Järvilehto 2000). In the history of psychology this approach may be connected with the ecological tradition that emerged from the work of J.J. Gibson. Gibson was critical towards the point of departure of behaviorism and cognitive psychology, which both analyse behaviour as a linear path from stimulus to reaction and consider psychological phenomena as information processing or creation of internal representations (Gibson 1961, Gibson 1979). Following Gibson, Järvilehto claims that "in any functional sense organism and environment are inseparable and form one unitary system,"(Järvilehto 1998a, p. 317). Järvilehto argues that the separation of man and environment is the very assumption that nourishes the conceptions of mental activity as a linear processing of information from the environment, and as an inner private activity. Hence, people are seen to be dealing with internal models and not with objects of the external world.

When an action of animal or human is usually preceded by a change in the environment it is understandable, from a common sense point of view, that the action is interpreted to be caused by that external change. Such connections were the natural first targets of psychological analyses. Although later psychological studies aimed at understanding more dynamic and complex adaptive forms of behaviour, the complexities of these performances forced the investigators to reduce their experiments to simple and strictly controllable stimulus-reaction situations. This practice was strengthened as it produced results, i.e. reproducible regularities between the stimulus and actions of the subjects. Järvilehto noted that whereas the prevalence of the stimulus-response paradigm becomes understandable through such practical reasons, it also has definite philosophical backgrounds in the much earlier ideas of Rene Descartes. The great mathematician and philosopher considered that in the study of living beings the unit of analysis should be the linear connection between the stimulus and reaction, the reflex. A Cartesian way of thinking became the leading paradigm in psychology. (Järvilehto 1998a) Consequently, it may be stated that despite the vast amount of research in psychology we still have problems in understanding the regulation of human action, its purposefulness and adaptability. These problems were also cited by those investigators who associated themselves with the naturalistic decision-making approach (Klein et al. 1993).

Järvilehto (1998a) reasoned that if the investigators insist on maintaining the idea of two systems it would become necessary to define the border between the systems. With several examples he showed that fulfilling this logical requirement encounters great difficulties. Correspondingly, it is very difficult to define the organism unequivocally. Therefore Järvilehto proposed adopting the idea of a unified organism-environment system. According to this conception, the living organism is constituted of integrated cells and tissues and of specified parts of the environment with which they form a system in which the behaviour is realised. Behaviour is thus not the movement or interaction of two systems, but the action of only one system as its organismic and environmental elements are organised or re-organised. A positive result is necessary for the survival of the system. Hence, the architecture of the organism-environment system corresponds to the outcomes, and its behaviour may be understood in the light of emerging outcomes. Whereas the outcomes manifest themselves in the materialised products, their significance does not lie in their material form as such but in the new possibilities they create (Järvilehto 1998a). In an environment-organism system all parts of the system are active with regard to the outcome. Therefore, environment is not something passive that surrounds the organism, neither is mental activity located in the organism but extends into the environment.

Järvilehto demonstrated the unified human-environment model through re-interpreting the stimulus-response situation. Because the experimenter has created the stimulus as an *event* in relation to which the reactions of the actor are scrutinised, he or she sees this event as a cause of the actors's reaction. From the point of view of the actor, whose behaviour is to be explained the stimulus has a totally different significance. It is an integral part of the activity that the organism through its history has achieved in order to enable the resulting response. Essential is that this enabling activity of the actor-organism has started long before the appearance of the signal. In fact, the signal is only a signal "because a preorganised system that defines some environmental change as a stimulus is present already before this change appears" (Järvilehto 1998a, p. 328). From the above it follows that, from the agent's point of view, the stimulus is not a cause of the reaction but a necessary element to produce the result, the reaction. Järvilehto illustrates this important idea by making an analogy with a jig-saw puzzle. It makes as little sense to claim the signal to be the cause of a reaction as to say that the finished jigsaw picture is caused by the last piece in the puzzle. In both cases the outcome is the co-ordinated organisation of all the necessary elements.

From the conception of Järvilehto follows that being in the world constitutes such action, in which the whole organism connects with the parts of the environment. Through this action of the system the environment becomes defined into parts that are meaningful and valuable objects or tools for achieving outcomes. Tim Ingold has developed a unitary system perspective to human conduct, which is in accordance with the above-cited ideas of Järvilehto (Ingold 2000). Ingold stated that understanding the development of action as a function of the unitary system demands a perspective which "situates the practitioner right from the start in the context of an active engagement with the constituents of his or her surroundings" (Ingold 2000, p. 5). Ingold described his view of action as a "dwelling perspective". This he understood as the ecological perspective to action. Social relations among human beings are one aspect of all the ecological relationships in the world.

We adhere to the above-described unitary system point of view. The "dwelling perspective" appears to be a suitable approach for understanding the situated construction of action. The task for the research that attempts to reveal the organisation of action is to determine what are the possible outcomes of action and what parts of the environment are functionally essential for achieving the results. The environment may be seen as a source of constraints and of possibilities for action.

2.3 Outcome-critical features of modern working environments: dynamism, complexity, and uncertainty

In this section we shall deal with the generic environmental features that characterise modern work. The outlined features have an impact on the achieving of the aimed outcomes of action and therefore they must be taken into account and balanced against each other. As a consequence, particular demands on action arise.

In his article "Coping with complexity: the psychology of human behaviour in complex systems" Woods (1988) presented a conceptual analysis of modern working situations. He defined a situation as a result of interaction between the world, the agent and the representation of the world. For Woods, complexity is a unifying characteristic of situations and results from four objective features of the environment: dynamism, many highly interacting parts, uncertainty and risk. Complexity of the situation is seen as being shaped through the way in which the environment is represented.

Our understanding of the decisive features of modern working environments has similarities with the above concept of Woods. We have, however, ended up defining only three features of the environment. These are *dynamism*, *complexity* and *uncertainty*. When coping with the environment people are obliged to take these features into account and to balance between them. Therefore, the features are outcome-critical and hence also relevant in understanding the construction of action in situations. In the following the term *DCU-environments* will be used to indicate the connectedness of these features through action. The concept also indicates that we do not see complexity as an umbrella concept under which the further features may be ordered.

Our conception of the nature and role of these generic environmental features of dynamism, complexity and uncertainty also deviates from that of Woods. Instead of taking these features as strictly objective features of the environment, we see them as resembling the notion of *affordance* that was introduced by Gibson (1977). Affordances are attributes of the environment that signal possibilities and constraints that have impact on the survival of a specific species living in that environment. They are real attributes of the environment. However, as they are not features of the environment as such, but features that are constituted through their relationship to an animal or human organism, they are not strictly objective. This reference to an organism does not indicate that affordances would be dependent on that organism, or that their significance for living would be related to the subject's valuing them. Here Gibson takes distance from the well known concept of "valence" introduced by Kurt Lewin. This notion refers to an environmental feature that changes according to the need state of the subject. (Gibson 1977, Lewin 1938). Hence, affordances are not subjective in the Lewinian sense of "valence"; although taking affordances into account depends of course on the subject. As different possibilities and constraints are always provided in the environment, taking into account and making use of these affordances constitutes the way of living of an animal or of a human. This conclusion has great relevance for the development of the Core-Task Analysis method later in the book.

The environmental affordances, the availability of possibilities for, and constraints on action are perceived directly as a result of the development of an organismic sensitivity to making use of them. Because affordances have meaning for action independent of becoming attended to or accounted for by a particular person, they have the same meaning to other people, too. The process of sharing the possible meanings of the environment through developing forms of communication makes the environment, and its affordances, objective and separate from an individual self, as was shown by Mead (1934). For bearing a shared meaning, affordances are objectified as signs in the external world, and these are interpreted via shared social practices. The comprehension of the relevance of the environment for the human aims must still be understood as immediate utilization of the environmental affordances in action, not as interpreting information represented in signs. Respectively, communication is shared action not transmission of information (Ingold 2001, Järvilehto 1994).

Gibson (1979) saw that the environment is a unity. An artefactual environment or the cultural environment is the same natural environment that the human being transforms for acquiring new affordances and, thus, further possibilities and results for action. However, Gibson maintained that some combinations of features in the environment are more, and others less perceivable. In the latter case some comprehension of the connections between the environmental features becomes necessary. Affordances of the environment become thus available for perception in a conceptually mediated way.

In the following the three generic outcome-critical features, dynamism, complexity and uncertainty will be briefly discussed. The intention is to show that as well as imposing constraints and providing possibilities, these features also shape the situated structuring of action. We have illustrated the interaction of these three features in the following model (Figure 1). The model demonstrates how balancing between the three environmental features creates different types of demands on action. Hence, constraints on skill, knowledge and collaboration emerge. These three aspects of action are mutually connected through their role in an appropriate and adaptive organisation of action. In the following pages we shall introduce each environmental feature, and demonstrate its relevance to the achievement of the results of action and, hence, to its organisation.

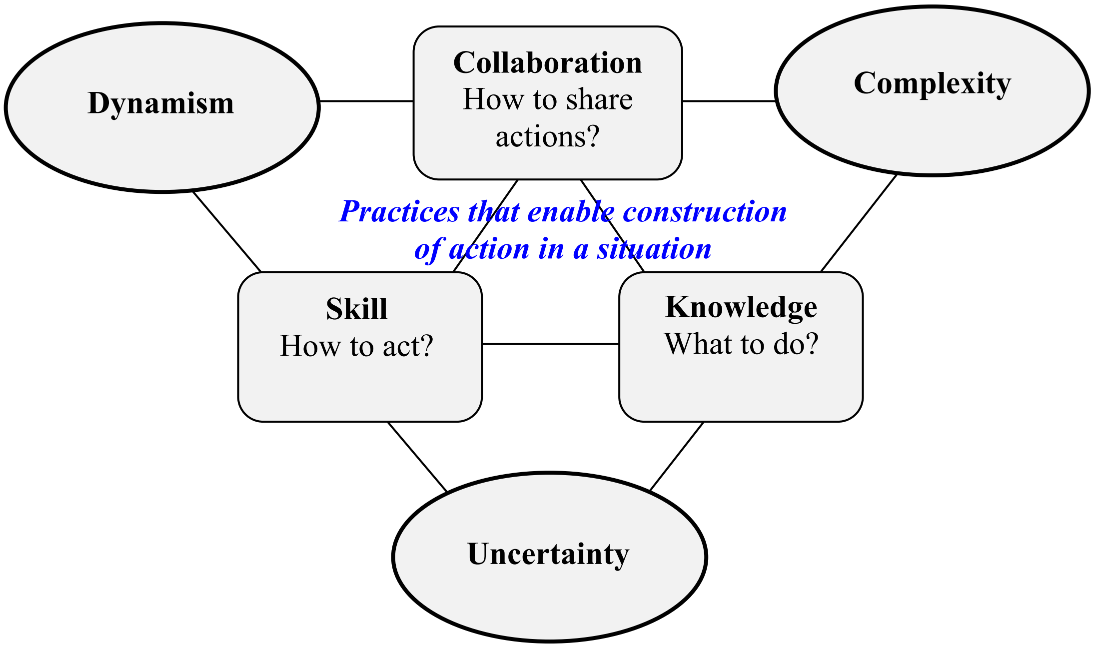


Figure 1. Model of the generic environmental constraints on action. The model depicts the three outcome-critical constraints of modern working environments, dynamism, complexity and uncertainty (DCU). Taking into account and balancing between these features create demands on skill, knowledge and collaboration in action. The demands are taken into account in practices that enable the construction of appropriate action in a situation.

Dynamism

Our environment is typically not stable but a process that is in constant change. Acting in a changing environment may be conceptualised as a system that has its characteristic dynamic features. There are four foremost characteristics of the dynamic system that may be considered to affect its control (Brehmer & Allard 1991). The first is the *rate of change in the process* to be controlled. There might be vast variance in the rate at which changes in a system take place, and the same system may have quite different temporal dynamics depending on the level of detail or functional aspect on which it is viewed. The second dynamic feature that affects the control of the system is the *relation between the process to be controlled and the control process.* The particular type of this relationship in each case has an effect on the strategy adopted in the control. Brehmer took an example of forest fire-fighting. If there is no wind the fire will spread as a quadratic process, whereas in the case of wind, as a linear process into the direction of the wind. The fire-fighting process, however, proceeds in a linear way because each unit can only supply water to a limited area at a time. The success of fire fighting depends on the extent to which the fire chief manages to match the fire-fighting process with the fire process (Brehmer & Allard 1991).

A third important dynamic feature is the possible *delays* in the system. By delays is meant the slowing down, or lagging behind, in the transmission of energy, or information in the system (Brehmer & Allard 1991). For example in steering and navigating large vessels the control of speed is complicated by long latencies in the change and stabilisation of the speed of the ship. Finally, it is necessary to mention the *quality of the feedback* information. It is evident that if feedback of the success of the control actions is lacking or is distorted, adequate control will be endangered.

Acting in such a dynamic environment could be characterised through the following features (Brehmer & Allard 1991, Edwards 1962, Hoc et al. 1995):

- An actor is asked for a series of decisions or actions, and sometimes it is also possible that the actor is able to correct his actions.
- The decisions or actions must be made at the correct point in time, which usually implies that the actor must adopt an anticipatory way of acting.
- The decisions or actions that are made in different times are interdependent.
- The environment changes both autonomously and as a function of the decision-maker's actions.

The described demands on decisions and action in real time are common in everyday life. However, as Brehmer notes, the dynamic features are not represented in the traditional decision-making models that reduce action to an event-related rational choice. Therefore, in reference to Broadbent et al. (1987) Brehmer and Allardt suggested that dynamic decision-making could be analysed from the control theoretical point of view. Thus one should analyse decision making in real-time decision tasks as an attempt of the actor to achieve control over some important aspects of the tasks. The authors assumed that the actors have three alternative methods of exercising control in dynamic situations: develop a mental model of the task, develop heuristic rules, or rely on feedback and modification of behaviour. The use of these possible methods was studied in a simulated fire-fighting task with undergraduate students as experimental subjects. The results that were replicated in further experiments show that the subjects learned to control the process with experience. However, they had difficulties either to perceive the delays in the feed back, or probably to understand the task well enough to make use of the available resources (Brehmer & Allard 1991).

The simulated fire-fighting study demonstrates that even if the control theoretical point of view may help in representing generic dynamic aspects of the task it does not inform us of the content of skilled action. The experimental task in the example was presented in the form of a fire-fighting task in order to constitute a meaningful content for this mental exercise, and to create minimum prerequisites for the subjects to mobilise their earlier experiences in dealing with dynamic phenomena. As the investigators noted, lack of understanding of the task hindered the subjects' exploitation of the available resources in the task. However, the authors conceived this understanding as an independent prerequisite factor for an adequate response to the task given by the researcher, rather than as an inherent part of the studied phenomenon, the skill of acting in dynamic environment itself. If it were, it would of course be more reasonable to study the skill of controlling dynamic processes in conditions in which such an understanding is available. This is automatically the case when action is viewed from the perspective of agents who are interacting intentionally with the environment that has meaning to them. In this example, this would have been the case if real fire fighters had been utilised as experimental subjects in the study. It should, however, also be necessary deliberately to change the research paradigm, as suggested by Järvilehto (1998a) and to view the skills as a result of the activity of the human-environment system, not as the subject's reaction to the experimental stimulus.

In his book "The perception of the environment" Tim Ingold provided an interesting account of action as skill or practice that has relevance for the development of a new paradigm focusing on action in a dynamic situation from an ecological perspective (Ingold 2000). Ingold saw skill as a form of use, in the sense that in practice the agent *brings* his or her hands and eyes, as well as his or her tools *into use* ...

"through their incorporation into an accustomed (that is usual) pattern of dexterious activity. Intentionality and functionality, then, are not pre-existing properties of the user and the used, but rather immanent in the activity itself, in the gestural synergy of human being, tool and raw material" (Ingold 2000, p. 352).

Ingold continued that skill cannot be regarded simply as a technique of the body, and as such isolated from the disembodied agency that puts it to work and from the environment in which it operates. Instead, the human organism should be restored to the original context of its active engagement with the constituents of its surroundings.

Much in the same spirit as Järvilehto above, Ingold articulates here the problem of the separation of the body and mind. It is a difficulty within the prevailing conceptions of human behaviour and it relates to the conception of the environment and the organism as two separate systems. This problem hinders understanding of the dynamic organisation of action.

The above mentioned problem of the separation between body and mind relates to the further problem that concerns the conception of knowledge. It may be claimed that knowledge of the dynamics of the environment, for example of the process to be controlled, expresses itself in the ability of the actors to control the process, in their skill of controlling it. Such ability is decisive in the achievement of a suitable result but it cannot be represented within the traditional conceptions of knowledge. This conception conveys the idea of knowledge as propositions of generic and law-like relationships in the world. Yet, skill or "know how" does not reduce to propositional "knowing that", nor does it equal instrumental and possibly strictly controlled decisions concerning application of knowledge (Ryle 1984, Schön 1988, Vehkavaara 1998a).

The main stream psychology on action demonstrates the prevailing epistemology that Toulmin describes as the modern focus on the written, the universal, the general and the timeless (Toulmin 1990). However, our everyday experience shows that although people do not have complete knowledge of the environment they are able to act adaptively in various situations. This seems to leave no doubt that people know (Vehkavaara 1998b). This point of view to knowledge has, according to Toulmin, more recently been broadened to include once again the oral, the particular, the local and the timely. Thus, the question of what is considered as knowledge becomes relevant for understanding adaptive behaviour in DCU-environments. The re-orientation has become evident in the ethnomethodologically inspired study of situated action and it is also typical to the pragmatist perspective.

According to pragmatist philosophy, skill, or practice, is a knowledge-process for coping with uncertainty that particular situations always entail. Thus, Dewey claims that practice is the foremost way to reduce uncertainty and to create knowledge of the particular phenomena of the world (Dewey 1999). Following this notion we have, in the above model of the environmental constraints on action (Figure 1), conceived skill as the aspect of action that connects with the dynamism constraints and responds to the problem of how to perform in a situation that requires action. Moreover, as the theory explains, skill simultaneously connects with the coping with uncertainty that the situation also entails. Thus, skill may be seen as an aspect of action that balances between the environmental features of dynamism and uncertainty.

Complexity

As we have seen, complexity is the feature that appears in many descriptions of modern work as the defining attribute of the working environment and a common denominator of various other features. Coping with complexity is seen to be the central demand for the human operator.

In concert with Woods and other authors (Brehmer & Allard 1991, Woods 1988) we see complexity to be related particularly to the number of elements and the nature of interactions within the system. Such an environment creates difficulties for the actor to orient, to diagnose its state and to control it. The psychological research tradition that has emphasised the need to describe the complexity of the world may be traced back to Egon Brunswik (1956).

Brunswik "emphasised the fact that the organism in his normal intercourse with its environment must cope with *numerous, interdependent, multiformal* relations among variables which are *partly relevant* and *partly irrelevant* to its purpose, which carry only a *limited amount of dependability*, and which are *organised in a variety of ways*. The problem for the organism therefore, is to know its environment under these complex circumstances." (Hammond 1993, p. 210, Tolman & Brunswik 1935).

Brunswik developed his lens model to represent the complexity of the environment from the point of view of making inferences regarding its state (Brunswik 1956). The model provides an experimental paradigm to simulate real-life judgements. For example a doctor's diagnosis of a patient is modelled through an experiment in which the subjects are supposed to learn to use a set of cues (symptoms) for making judgements (diagnoses) about an underlying criterion value (e.g. a disease). The relationships between the elements of the model are considered in probabilistic terms. Results of experiments have shown that subjects tend to diminish the complexity of the environment by reducing the number of cues they attend to, and by using positive linear relations that represent the connections between the cues. Subjects have difficulties in comprehending negative and curvilinear relations (Brehmer 1987a, Brehmer 1987b, Elstein & Bordage 1988). We found corresponding results in a study that dealt with the problems of learning complex relations and regulation of effort as a simulation of a process control task (Kasvio 1978).

If the actor has difficulties in making sense of the complex environment it is clear that learning from experience cannot be effective. In their classical studies Hammond and Summers (1972) and Brehmer and his colleagues (Brehmer 1980) showed that conceptualisation of the environment (cognitive feedback) promoted learning of complex relations better than knowledge of the results (outcome feedback). Later Barry and Broadbent also conducted experiments on process simulations and tackled the related question of the interaction between skill to control a system and knowledge of the system. The results may be interpreted as indicating that deliberate reflection of the task promotes building of a connection between conceptual knowledge of the system and the operative skills. (Berry & Broadbent 1984, Berry & Broadbent 1986, Berry & Broadbent 1987).

As the preceding examples indicate, complexity appears clearly to put demands on cognitive and knowledge-related aspects of human action. While providing possibilities for coping with complexity through reducing the number of cues to be paid attention to, knowledge processes enable interpretation of the situation and understanding of the uncertain environment. The relevance of knowledge processes in coping with the generic environmental features is manifested in the model depicted in Figure 1. Knowledge is the aspect of action that balances between complexity and uncertainty.

A well-known treatise of environmental complexity was offered by Charles Perrow in his book "Normal Accidents" (Perrow 1984). He distinguished two types of environmental relationships as significant for the mastery of situations. These relationships are the couplings and the interactions of the system, and they form dimensions from loose to tight and from linear to complex, respectively. The two dimensions are interpreted to constrain the ways of organising work. Work domains that are both tightly coupled and complex face contradictory constraints. Tight couplings require centralised control, whereas high complexity necessitates de-centralised control and corresponding forms of organisation.

Other authors have also drawn attention to the role of organising collaboration in coping with the complexity of the environment. Thus, for example, Hutchins emphasized the fact that the social distribution of actions is connected with the ways in which the environment and the problem are represented in the artefacts used in the action (Hutchins 1995). Van Daele and De Keyser (1991) analysed team communication in real life process control situations. Their results demonstrated that in the control of complex highly automated environments the demands on temporal synchronisation and co-ordination of actions in reference to the dynamics of the on-going process are solved through variable ways of co-operation within a team of actors. In air traffic control the regulation of the distribution of responsibility among controllers is used for adapting to the fluctuations of the rate of traffic (Schulman 1993). In a recent study Grote and Zala-Mezö studied the means of organising cooperation within airplain cockpit crews and anaesthesia teams in task situations that varied in complexity. Their results indicate that depending on the situational demands different forms of team coordination appear appropriate but that the connection between ways of cooperating and task performance also depends on the domain. In aviation explicit cooperation and compliance with rules that define courses of action improve performance. Acting in the operating theatre is qualified by higher uncertainty. Cooperation is more implicit, relies on expertise and process-oriented rules. Clear connections between ways of cooperating and performance could not be stated (Grote & Zala-Mezö 2004, Grote et al. 2004).

Thus, we may observe that collaboration is the major resource for coping with complexity in dynamic situations that require action. Collaboration helps in reducing complexity and thus enables proper functioning of the system. Therefore, we have conceived collaboration as a demand on action that reflects balancing with the complexity and dynamics of the environment in a situation, as Figure 1 indicates.

Uncertainty

It was not only complexity of the environment which attracted the attention of Brunswik and Gibson and the later proponents of ecological psychology. The other outcome-critical and, thus, relevant characteristic of the construction of a human-environment systems is uncertainty. As we have already seen, uncertainty is a feature that puts demands both on skills and knowledge.

Uncertainty is a many-sided concept. Firstly, one may take the point of view that the processes of the environment themselves are stochastic and cannot be expressed through deterministic rules or laws. For example clinical findings in medicine usually bear a probabilistic relationship to underlying causes that produce them. Only very few cues are in a one-to-one relationship to a particular disease. More often the cues are associated with several diseases (Elstein & Bordage 1988). This situation is modelled in the assumptions of the multiple cue probability learning paradigm (MPCL). Results from research using this paradigm indicate that the inference tasks containing stochastic elements are more difficult compared to those in which the relationships are deterministic. People do not appear to develop adequate statistical hypotheses for their diagnoses, and therefore they also have difficulties to learn from their experience with the system (Brehmer 1980, Brehmer 1987a). In such situations, and they are not rare, human actors must exercise their judgement, “the cognitive activity of last resort” as Hammond notes (Hammond 1993).

Another aspect of uncertainty relates to the nature of our knowledge of the environment and its objects. As a result of scientific practice it has been possible to define regularities in the world, that in respect to human action are robust enough to be considered as deterministic laws. Beyond this, there exist phenomena of which we have acquired only statistical knowledge. In this case, general statements concerning the phenomena apply with certain probabilities. There is no way of knowing whether the statement is true in an individual case. This is certainly a problem for a practitioner who is supposed to act on the phenomenon. He or she is obliged to build up hypotheses on whatever knowledge is available and to make judgements, unless he interprets the statistical knowledge falsely to provide him or her a deterministic rule.

Lipshitz and Srauss studied conceptions of uncertainty and how decision-makers cope with uncertainty (Lipshitz & Strauss 1997). They first analysed the conceptions of uncertainty in the decision-making literature between 1960 and 1990. The result was that there is a conceptual proliferation with regard to the term. The authors attempted to clarify the theoretical confusion through an analysis of the concept and an empirical study. With reference to Dewey they considered uncertainty in the context of action and defined it as a sense of doubt that blocks or delays action. With the help of reports written by their subjects about situations in which they had experienced uncertainty, the authors were able to elaborate the concept of uncertainty. They also proposed a heuristic of coping with uncertainty, mostly experienced in relation to assessment of the situation. It seems that

- people tend to attribute uncertainty to subjective sources (inadequate understanding and undifferentiated alternatives) rather than to objective sources (incomplete information).
- people cope with inadequate understanding (subjective source) through a strategy of reduction, i.e. either by trying to gather additional information or by using rules and guidelines
- in the case of conflicts (subjective source) about the alternatives subjects often choose a strategy of weighing pros and cons.
- incomplete information (objective source) is coped with using what is called "assumption-based reasoning" that is qualified by building up hypotheses that are retracted and reformulated in the case of new relevant information
- suppression is a coping strategy that basically ignores uncertainty. It is not very frequent and not related to any particular source of uncertainty.

The results of Lipshitz and Strauss inform us about peoples' ways of interpreting and coping with uncertainty in action. In the light of these results, it appears that the above mentioned two perspectives to uncertainty both illustrate situations in which uncertainty has an objective source (incomplete information), and would, if interpreted as such, be coped with an assumption-based reasoning. As Lipshitz & Strauss pointed out, using assumption-based reasoning experienced decision-makers can act rapidly and efficiently within their domain of expertise with very little information. We interpret assumption-based reasoning to denote the same process that Hammond in the above cited reference called "cognitive activity of last resort", i.e. judgement. Both are defined to rely on the formulation of hypotheses, which are tested on the bases of only very few cues of the phenomenon. Utilising this last resort assumes insight into the objective nature of the uncertainty in the environment. But as Lipshitz and Strauss reported, the tendency of attributing uncertainty to subjective sources was found dominant, and the typical coping strategy was found to be reduction. It is also likely to be used in situations where uncertainty can be considered objective, i.e. it is due to uncertainties in the object processes or to the statistical nature of knowledge. In these cases the reduction to a rule would be less adequate than utilising assumption-based reasoning.

Hammond characterised judgement (or assumption-based reasoning) as the last resort (Hammond 1993). In naturalistic everyday situations uncertainty is high and people are able to act just because of this resort. But what is the nature of this last resort? As indicated above Lipshitz and Strauss (1997) define uncertainty as doubt that prevents action. We agree with this notion and add that according to Charles Peirce the particular form of creative inference, abduction, allows to overcome doubt (Peirce 1998a). An abductive hypothesis takes the form of "is it possible that…". It is an inference that in particular is oriented towards cues. It provides possible explanations of the phenomena that these particulars denote (Paavola 1998). Abduction may be seen as the basis of the assumption-based reasoning identified by Lipshitz and Strauss. However, coping with uncertainty is not seen as a purely intellectual action. Peirce, and later other pragmatists, Dewey and Mead, pointed out that there is an analogy between intellectual learning and more corporeal skill acquisition and that they both reflect the structure of abduction (Kilpinen 2000).

The pragmatist emphasis on the similarities between intellectual learning as enhancement of knowledge, on the one hand, and the processes of acquisition of skills on the other, has connections with the more recent practice-theoretically and phenomenologically oriented ideas of Ingold (2001) concerning knowledge and learning. Ingold argued that the common sense conception of knowledge – that also prevails in cognitive science – bases on incoherent assumptions. He referred to the ideas that, firstly, knowledge reduces to information, and, secondly, that human beings are devices of processing and storing information in some form of representations. Ingold maintained that these misunderstandings distort our conceptions of learning and transformation of knowledge over generations. His alternative view is that knowledge consists, in the first place, of skill, and that every human being is a centre of awareness and agency in a field of practice that he calls "taskscape". This term contains an analogy to landscape in which we may be situated and through which we make our way. In the analysis of the growth of knowledge he proposed focusing on the emergent properties of the dynamic organism-environment systems. Skills are such emergent properties. Ingold noted that his conception of the emergence of action and knowledge in the field of practice resembled that of Hutchins who wrote that

"instead of conceiving the relation between person and environment in terms of moving coded information across a boundary, let us look for processes of entrainment, coordination and resonance among elements of a system that include a person and a person's surroundings" (Hutchins 1995).

The adoption of the practice-theoretical point of view to the ontogenetic development of human beings lead Ingold to the conclusion that the growth of knowledge, the contribution that each generation makes to the next, is not an accumulation of representations in a process of copying what other people do. Rather it is following what other people do in a process of guided rediscovery, requiring an education of attention, an expression introduced by Gibson (1979).

With respect to the model of the environmental constraints on action (Figure 1) we may conclude that coping with uncertainty creates demands both on skills to act and on understanding of the situation. Skill and knowledge impose each other mutually. Skills express balancing between the uncertainty of the state of the world and the simultaneous need to cope practically with its continuous change. At the same time knowledge processes create possibilities to survive in the environment. They facilitate coping with inadequate understanding by reduction of complexity, and they also enable reflection on the inherent uncertainties of the environment for providing hypotheses to be tested in practical action.

2.4 Cues as signs in making sense of DCU-environments

Egon Brunswik deliberately distanced himself from the traditional idea of experimental psychology to minimize the complexity of the environment in order to identify the genuine psychological phenomena (Hammond 1993). He considered that such reduction was an inadequate strategy when attempting to reveal behavioural regularities (Brunswik 1956). His lens model expressed an effort to create representative sampling of the complexities of the situation in the experimental analysis of behaviour. The term ecological validity was introduced by Brunswik to indicate the relevance of the perceived cues with regard to the comprehension of the object. The subjects' utilisation of the cues is conceived as an inference process that results in a judgement of the situation. This view corresponds to the everyday usage of the term cue in English language. Cues are understood as pieces of information that relate to a distal object and, moreover, provide a signal for action (Pearsall 1998). Thus, the cues enable a mediated comprehension and control of the environment via their interpretation by the actors.

Although Brunswik's work was not initially very widely accepted, it was valued by Gibson (1961). However, instead of concentrating on the probabilities of the relationship between the cues and the object, as Brunswik did, Gibson attempted to solve the question of the relationship between the environmental features and the perceptual units as a geometric problem. In this conception, perception of environmental information reflects the organism's ability to tune or sensitise towards the environment (Gibson 1974). Hence, perception is viewed as a direct or immediate process and as a function of a unified system. The concept of affordances that Gibson later introduced provided a functional explanation of the role of the geometrical information in the organism-environment relationship (Gibson 1977).

Differences in the availability of combinations of environmental features for perception can be comprehended by the theory of signs. According to Peirce there are different types of signs that all are necessary in perceiving the world as significant for action. In his theory of signs Peirce conceives the human environment as a set of cue-like signs, and claims that the interpretation of these signs characterises our thinking in general (Peirce 1991, Peirce 1998d). Peirce distinguished three types of signs, *icons or likenesses, indications or indexes, and symbols.* A mixture of these signs is utilised in all reasoning. The three orders of sign form a regular progression of one, two, and three:

"The likeness has no dynamical connection with the object it represents; it simply happens that its qualities resemble those of that object, and excite analogous sensations in the mind for which it is a likeness. But it really stands unconnected with them. The index is physically connected with its object; they make an organic pair. But the interpreting mind has nothing to do with this connection, except remarking it, after it is established. The symbol is connected with its object by virtue of the idea of the symbol-using mind, without which no such connection would exist" (Peirce 1998d, p. 9).

Indication shows something about things and connects to or denotes something else. This connection develops through experience with the environment. The cues have the function of an indication. The cues used by the operators of modern technological processes are indications of the state of the process and of the need for action. These cues are today almost exclusively provided in the form *symbols*, in numbers and letters, or in graphical symbols such as curves. Symbols are general signs that have become associated with their meanings by convention or usage. Earlier, however, the cues were rather constructed in the form of *likenesses*, or *icons*. These convey ideas of the things they represent simply by imitating or describing them. In the technological surroundings the movement of the hand of a pressure gauge is a likeness in relation to the increase in pressure. The coloured marks indicating alarmingly high levels of pressure provide a reference for the interpretation of the likeness.

Peirce considered it important to emphasise the difference in the roles of icons and indications. Because one and the same sign may be at once an icon and an indication, e.g. a map is icon but also an indication if having references to known localities. Both icon and indication appear, initially, to require experience. However, Peirce maintained that the icon does not only require experience in order to be understood but, even more, in order to be perceived. Peirce writes:

> "for it is *not* experience, but the *capacity* for experience, which they show is requisite for likeness; and this requisite, not in order that the likeness should be interpreted, but in order that it at all should be presented to the senses. Very different is the case of the inexperienced and experienced person meeting the same man and noticing the same peculiarities, which to the experienced man indicate a whole history, but to the inexperienced reveal nothing" (Peirce 1998d, p. 8).

Peirce maintained that in order to be *informative* both symbols and icons require an indication that draws the attention and connects the sign to a known frame or object. In the case of the icons the indication is created through experience with the environment in a perceptual non-reflective way, whereas in the case of symbols the indication emerges in a more deliberate and conceptual way. Thus, due to the need to be connected to a known reference, the signification through any sign is conditional in that it is possible only within a particular cultural context. Juri Lotman, who distinguished only two types of signs, the descriptive sign (the icon), and the conditional sign (the symbol), also emphasised the conditional nature of all signs. Furthermore, the descriptive icon, not only the symbol can be interpreted only within a particular culture (Lotman 1989).

The understanding of the particular role of indications and the differences between icons and symbols has relevance to conceptualising modern work in CDU-environments. The differences in the use of signs in traditional and modern working processes are not only related to the prevalence of either icons or symbols in our environment as such, but also to the way in which the necessary indications are created. In traditional process control, experience that was needed to frame the iconic signs was perceptive and intuitive. Modern ICT-mediated process control rooms are overwhelmed by symbols that must be deliberately and conceptually connected to the underlying process. Following Peirce the task of the operator in this situation is to imagine the underlying phenomenon and create the association, and, moreover, because the symbol is a general sign, he is required to connect it to the particular situation of its use. These processes are indispensable for the symbol to be informative in action. Zuboff pointed out the growing demands on interpretation as a result of the increase of textual information in process control (Zuboff 1988). She stated that a two-step interpretation is necessary when the processes are controlled through textual information.

In recent years ICT technologies have created new possibilities for the measurement of process states and opened new ways of presenting information in user interfaces. The availability of these enabling technologies has raised expectations for more natural or intuitive ways of interacting with the environment. In the light of the theory of affordances, new technologies create new possibilities in the environment only in relation to the developing practices of the human user. The theory of signs shows that developing the ability to make use of signs as conveyers of possible meaning for action assumes experience-based building of referential indications. Intuitive interfaces are not simple solutions to the problems of orienting in a complex environment. They require the formation of meaningful connections to the environment through experience in a community of practice.

2.5 Consequences regarding an ecological research methodology

Process control work is characterized through features that have become common qualifiers of work in modern society. Therefore, the research on process control should also, in principle, have relevance for the understanding of the nature of expertise in today's working life. In the psychological literature, process control has overwhelmingly been dealt with as an internal human information processing problem, in particular as a problem of cognitive *coping with complexity* (Cellier et al. 1997). The successful maintenance of the stability of the production process is seen to be the effect of the adequacy of the internal representation of the process. The research interest therefore focuses on the compatibility of the internal model with the objective reality. However, the concrete contents of the internal models have interest to the researchers mainly with respect to illustrating generic regularities of achieving compatibility between the external world and the model. Hence, the analysis results in context-independent conceptions of information processing that are then applied (back) to the problems of process control. The achievements in process control studies do not raise general interest within psychology just because the results are so general! This seemingly contradictory claim indicates that because similar results are achieved in other studies, in which the research settings are less complex, they do not require too much domain knowledge and they are better controllable, the researchers in psychology rather orient to them.

As we have seen, the ecological approach conceives the operators as being in an active engagement with the actual production process and its real constraints and possibilities for action. In other words, the operator's mental and practical actions are seen to focus on the process, not on its internal model. By acting on the real process the operator creates knowledge about it and in this way he attempts to cope not only with the complexity of the object but also with the contingencies of the phenomena. *Uncertainty* about the contingencies of the process is the foremost problem for the operator, although the possible complexity of the phenomena and the need to act timely in the dynamic situation apply further constraints. Viewed from the ecological perspective, process control becomes interesting for its own sake. Due to its peculiar features process control activity clearly demonstrates the generic features of acting in the DCU-environments. Studies on process control may demonstrate the philosophical idea that making sense is a result of both an operative and an epistemic relationship with the world (Dewey 1999). Thus, when adopting an ecological perspective, process control is both skill of controlling the process, and creation of knowledge through the control for a better control. The information processing approach reduces this work to mere control of a given and principally known object. The epistemic aspect is often neglected.

If we adopt an ecological perspective to the object of our inquiry the research process itself must also be reconstructed. To use Lipshitz's (in press) terminology we conceive the research process as an interpretative process in which the investigator is actively making sense of his object, rather than objectively recording and decoding word for word the phenomena. In the following we shall present the methodological principles that we consider as central tools in an interpretative research process.

Interdisciplinary modeling of the human-environment system

When we adopt an ecological approach, according to which the human (self) and the environment are not strictly separated, the problem arises of how we should understand scientific objectivity (Klemola & Norros 2000). In the positivistic methodology objectivity is usually understood as the detachment and neutrality of the investigator from his or her object of inquiry. This traditional conception of objectivity was labelled as absolute objectivity by Megill (1997). This notion of objectivity had already been criticised forcefully by Thomas S. Kuhn (1970). An emerging conception of objectivity, that Megill calls dialectical objectivity, assumes that subjectivity must be taken into account with regard to both the investigator and the investigated human actor. This conception states that subjectivity is a prerequisite for objectivity in the sense that the object is readily created in the personal acting in the world, in the communicative interaction between the inquirer and the object. Thus knowledge is constructed under specific circumstances and has a specific situation, a point of view that was also strongly emphasised by Dewey (1999). The search for more adequate knowledge is tied with overcoming subjectivity in a reflective process that assumes awareness of the limitations of one's own position, and of the societal determination of the available concepts (Bourdieu 1990). Interaction and communication within different views enhance reflection.

Due to the above-described nature of the human action and the nature of our knowledge of it, the comprehension of a this object is necessarily limited (Klemola & Norros 2000). From a realistic point of view a communicative interaction with the object is a prerequisite for construction of knowledge. The argument developed by Klemola states that this interaction might be enhanced through a diversity of views and interdisciplinary research.

Subjectivity of knowledge of objects also implies that knowledge is embodied or located. In other words the circumstances of action have an effect on how events are conceived and what actions are taken. Klemola (Klemola & Norros 2000) referred to the concept of Longino (1999) regarding the three aspects of the *contextual dependence of action.* There is a contextual dependence through the individuality of subjects, through the community and its history, and through the constraints of the actual situation. It is widely agreed that all these three aspects must be taken into account in a valid research methodology of human action. However, the development of concrete contextual methods for the study of situated action has turned out to be a rather complex task.

Understanding the particular content of particular actors' work is not possible for an observer outside the domain. Therefore, an adequate analysis of action in context necessarily requires not only interdisciplinary co-operation within the research group but also intensive co-operation with the domain experts, and the subjects whose work is being studied. Thus, for example, in our studies in the domain of nuclear power plant operations we have conducted developmental research processes in the field in co-operation with operators and technical experts of the plants. The research teams were composed of psychologists, reactor physicists, reliability engineers and simulator instructors with a background of power plant operations. The work of such a team should, as much as possible, take the form of interdisciplinary collaboration, in which the actors have the same object and they share (at least some) conceptual tools, with the aid of which possible divergent views may be interpreted. An advanced interdisciplinary research team was also formed in our study on anaesthesia, in which the team consisted of an expert anaesthetist and a psychologist, and, in certain phases of the study, of medical engineers. The central task of the interdisciplinary teams in these examples was to create a model of the objective of activity, and constraints and possibilities of the domain. This model would provide a reference for the analysis of actions.

Activity as the context of explanations

The second methodological principle deals with the type of assumptions that the investigator makes regarding relevant explanations of human conduct. Eskola crystallised the problem as a choice between the deterministic and the realistic research paradigm (Eskola 1999). He defined two underlying ideas of most social science. The first indicates that the phenomena to be explained are determined by certain factors, not directly but through mediating mechanisms. Consequently, investigators define variables that represent the studied phenomenon as dependent variables, and those that should explain it as independent variables. Observed correlations between these sets of variables are interpreted as general psychological, social etc. laws, and they exert their influence through mediating mechanisms. The other idea is that explanatory factors are restricted to two sources, those hidden within the individual and those in the environment. The history of psychology is characterised by the shifting of the explanatory emphasis from one of these sources to the other.

Eskola labelled the above described research paradigm as mechanistic-deterministic, and claimed that research following it tends to become entrapped in the above-mentioned dichotomical decision situation (Eskola 1999). Therefore he argued for another approach. He took an example of explaining the participation of a scientist in a scientific conference. Eskola "refused to believe" that most of participants attend conferences because they are certain types of personalities or that the site of the conference is that attractive, or the situation at home intolerable. A much more plausible explanation would be that they want to participate in an activity called "the international congress of psychology", for example. He continues:

"I am sure that the concept of *activity,* could add an important new step to those analyses that now stop short at the concept of situation" (Eskola 1999, p. 109).

Eskola commented on the conception of situation by emphasizing the importance dividing it into two parts. Some aspects of situations provide cues for understanding what the behaviour we are explaining may mean as an activity, whereas others are "only" part of the environment (Eskola 1999, Gibson 1977, Järvilehto 1994). The investigator should try to identify those of the first type and start the analysis from the activity. In such an activity-oriented and realistic paradigm the investigator is not distinguishing the dependent and independent variables. Instead he defines, first, the structure and development of activity and its meaning to different actors; second, the laws and rules that actors take into account in this activity; and, third, the logic on the basis of which they do so (Eskola 1999). This approach does not deny the existence of laws and rules but states that an individual's activity is free in the sense that he may choose whether or not and how the rules and laws are taken into account. The cultural-historical theory of activity, including its recent developments in the area of work research, provides a comprehensive activity-oriented frame for the analysis (Engeström 1987, Leont'ev 1978, Vygotsky 1978).

Reason-based explanations for understanding situated action

A contextual process-tracing analysis of actions is usually conceived to require a decoding from the domain-specific language to a content-independent cognitive language in order to reach generic and useful results (Woods 1993). The problem is that after decoding to the cognitive language the content of actions usually disappears and the description of psychological phenomena becomes abstract and inconceivable.

An analogy from the history of art helped me to understand what type of solution could resolve the conflict between context-specificity and context-independence. In an academic dissertation from 1946 regarding the art of Paul Cézanne Göran Schildt explained the attempts of the artist to distance himself from the naturalistic illustration of the world that was the prevailing way of painting at his time (Schildt 1995). Cézanne's life-long analysis of his own way of perceiving the world aimed at finding the method of creating an independent painting that would invite the person through his or her perception of that painting to reconstruct the object as a motive with aesthetic meaning. Schildt proposed that Cézanne clarified his conception of an adequate method by contrasting it to the prevailing illusionist approach in painting.

> "When the former (the illusionist, LN) is making all the effort to transforming the canvas into a transparent window the latter (an artistic painter LN) accepts the surface of the painting as a primary reality, the function of which is to denote the existing three-dimensional reality but not to substitute for it. In this sense Cézanne is anti-illusionist to a hundred percent. As precisely as he perceives the target in three dimensions, as consequently he also grasps the piece of art in two dimensions. … Cézanne has found an apt expression to make this distinction: I do not model, I modulate" (Schildt 1995, pp. 126–128).

One of the emerging technical solutions of Cézanne was to reject the central perspective, an objective observer's point of view that, later, the person observing the painting must also adopt. Instead of placing the human outside or above the world, his attempt was to create a harmonious presence in the world.

By analogy, the psychological methodology that we are seeking should not illustrate action from outside and describe the endless details of the behavioural or neural events. Instead the analysis should use vocabulary that allows the observer/reader to make sense of, or reconstruct the subject's logic that has led, or may in the future lead, to certain courses of action in particular situations. The vocabulary of a valid method for the study of situated action should explain the organisation of performance through the content-related meaning of action to the actor. Consequently, there would be no need for decoding, and one vocabulary would suffice. The methodology presented in this book is built on this basic idea.

Another important question to consider in developing an ecological methodology for explaining human action is how the intentional agency of a human being is related to the physical phenomena of the brain and body. Georg Henrik von Wright offered a new conceptualisation of this traditional mind-body problem (von Wright 1998a, von

Wright 1998b). He distinguished three kinds of primacy relationships between mental, neural and behavioural phenomena. Demonstrating his idea with the help of the scheme depicted in Figure 2, he argued that mental states have epistemic primacy over neural, because in order to verify neural processes that relate to e.g. auditory sensations we already have to know that the subject has such sensations. This we know with the help of behavioural, often verbal criteria. This is also valid with regard to reasons for actions. To know the reason for an action we normally ask the person for example "Why did you turn your head?" The answers may be "There was a loud noise" or "I was frightened". If the subject does not give an answer or we doubt the truth of a given one, we may apply other behavioural criteria, e.g. knowledge of typical hormonal reactions when frightened. In this case as well, before we can use internal bodily criteria we must already know what it is to be frightened. Thus from an epistemic perspective, mental states are primary in this case as well.

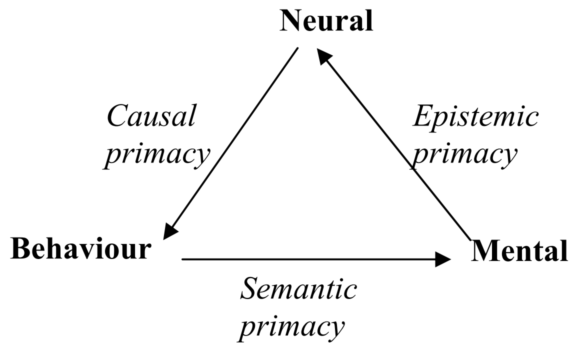


Figure 2. Three types of primacy relationships that describe the ontological diversity of the objects of research in psychology (von Wright 1998b).

The use of behavioural or in the case of human beings verbal criteria as truth criteria of mental states implies that the relationship between the behavioural criteria and mental states is semantic. The behavioural criteria explain what it means when we say that a subject has a particular mental state, such as being frightened. Thus, von Wright infers that behavioural is semantically primary in relation to mental.

Finally, in order to say that an organism's movement is behaviour, not mere mechanical movement, it must be assumed that the movement is an effect of internal processes of the body, of the nervous system or something like it. Consequently, neural is causally primary to behavioural.

Psychology as a science cannot be reduced to either the study of behaviour, neuroscience or introspective phenomenology. The ontological diversity of the objects of research in psychology is what makes it so interesting. Von Wright concluded that instead of differentiating between two substances, mind and body, we could conceive two kinds of approaches to living organisms.

"One way is to relate causally the behaviour of living organisms to the internal (neural) states and processes. The other way is to understand what is behaviour a sign of, what is its meaning. The latter way is the one that makes the study of behaviour and its internal causes *psychology*" (von Wright 1998b).

In our methodology we attempt to follow the perspective of understanding what behaviour is a sign of, what is its meaning and to explain actions on the basis of their reasons. Explanations based on reasons are what von Wright calls *understanding explanations* (von Wright 1985, von Wright 1998a).

Following both Eskola's and von Wright's advice we choose to explain human actions through the meaning they express. Inferring the personal psychological sense of action requires analysis of both the intentions and the personal accounts of the generally meaningful system of activity in which actions are embedded, and the significant environmental constraints in the actual situations. Consequently, we carry out a semiotic analysis of practical actions. This analysis is grounded in the pragmatist's conceptions of thinking and habit (especially in the writings of C.S. Peirce, J. Dewey, and G.H. Mead). As a result, a conceptually defined way of analysing work practices emerged.

The above-described methodological principles define the rules for synthesising elements of theoretical approaches that we considered relevant for an ecological analysis of work that we labelled the Core-Task Analysis.

3. Analysis of situated action in an activity system context

The Core-Task Analysis methodology emerged gradually in the course of empirical studies of modern high technology working activities. In this chapter we shall introduce the conceptual underpinnings of CTA. Guided by the tenets outlined in the preceding chapter we are seeking ecologically oriented ways to explain the situated construction of actions. Thus, neither the environment nor the human actor should be treated independently of the other. The notion of affordance satisfies this qualification as it provides a way to view the environment in its relation to the actor. The environment is perceived from the point of view of its use in human practice. We need a corresponding perspective for the description of human conduct. The notion of intentionality refers to the relationship between the human being and his or her environment. Hence, we are interested in theoretical approaches of action that emphasise intentionality of action and acknowledge this feature in the research methodology.

With the above-mentioned expectations we shall consider the system theoretical modeling of work domains, the cultural-historical theory of activity, and the pragmatist conception of habit and make a conceptual synthesis of them. The chapter will be closed by the presentation of a conceptual model of the situated construction of action. This model provides the basis for the Core-Task Analysis (CTA) method that aims at understanding the development of work practices.

3.1 On the intentionality of action

Intentionality denotes human and social phenomena that have meaning or reason outside themselves, are about something or directed at something (Searle 1984, von Wright 1998a, Von Wright 2001). From an ecological perspective intentionality of action is seen to emerge in the dynamic unity formed by the human and the environment. In a previously cited reference Ingold stated:

… "Intentionality and functionality, then, are not pre-existing properties of the user or the used, but immanent in the activity itself,…" (Ingold 2000, p. 352).

Following Ingold we may propose that functionality is a feature of the environment that becomes manifest to the human as affordances of the environment for action. Intentionality may be seen as a feature of human conduct that expresses the meaningfulness of human behaviour. Meaning in action is in the pragmatist theory tackled as learned dispositions to act, as habits. Both affordances and habits express generic potential to construct relationships between the human and the environment and therefore they are central concepts in the ecological approach that we are developing for the study of action.

Two notions of intentionality

The notion of intentionality is commonly conceived to have two important ways of use in philosophy and social theory (Aho 1989, Dennet 1995). The first relates to the philosophy of action and comprehends "intentionality" as a characteristic of action denoting purpose, aim, or a goal towards which an action is striving and in which it finishes if successful. In the present everyday use intention is understood as an aim or also, a plan (Pearsall 1998). This conventional meaning of the term originates in the early Middle Ages and resembles the interpretation it later acquired in the philosophy of action. Intentionality was introduced to the philosophical discussion in the book titled "Intention" by G.E.M. Anscombe that was first published 1954 (Anscombe 1957). The studies of the Finnish philosopher Georg Henrik von Wright significantly contributed to the philosophical discussion on this topic (Niiniluoto 1989, von Wright 1963, von Wright 1971).

The other use of "intentionality" relates to the philosophy of psychology and logic and connects with the theory of meaning, and also with the theory of attitudes. In this context, the term denotes aboutness or content, and it is understood as consciousness of the human mental phenomena and their generic directeness towards an object as a target. This interpretation of intentionality is usually seen to originate in the work of Franz Brentano, whose book "Psychologie von empirischen Standpunkt" was published in 1874 (Brentano 1924–1925). This interpretation was adopted in 20th century phenomenological philosophy.

Motor intentionality in explaining adaptive action

In the current theoretical discussion the two uses of the concept of intentionality express two ways of conceiving human action and corresponding forms of intentionality. They have been analysed thoroughly for example by Hubert L. Dreyfus, John Searle and Frederic Stoutland. Because the distinction between these uses has relevance for our attempt to formulate an ecological methodology for the analysis of action, we shall in the following take up some points of this discussion, mainly with reference to the recent articles by Hubert L. Dreyfus (Dreyfus 2001) and Frederick Stoutland (Stoutland 2001, Stoutland 2002). In his article Dreyfus summarises the discussions with his colleague John Searle about the conceptions of intentionality and action (Dreyfus 2001). These discussions extended over many years (Dreyfus 1991, Dreyfus & Wakefield 1991, Searle 1991, Searle 1995). Dreyfus opens the article by defining the initial point of view of Searle. He writes that according to Searle, a movement must be caused by an intention to be an action. Intention is understood as a propositional representation of the action's conditions of satisfaction. This form of intentional action may in short be called *representational intentionality*. Dreyfus contrasts this conception of intentionality with the phenomenologically oriented notion of *absorbed coping of* Merleau-Ponty (1986). It provides the second way of understanding intentionality in action. In absorbed coping such a representation of the conditions of satisfaction is not needed, instead a feel of the distance from a satisfactory gestalt directs action. (Dreyfus 1991 and 2001)

"the agent's body is led to move so as to reduce a sense of deviation from satisfactory gestalt without the agent knowing what that satisfactory gestalt will be like in advance of achieving it. Thus, in absorbed coping, rather than a sense of *trying to achieve success,* one has a sense of *being drawn towards an equilibrium*" (Dreyfus 2001, p. 2).

Absorbed coping could, thus, be understood in terms of reduction of tension in the human-environment system (Dreyfus & Wakefield 1991).

Searle accepted the existence of what could be named absorbed coping but he maintained that it is not necessary to contrast it with representational intentionality. Managing situations as absorbed coping may, according to Searle, be taken into account in an enlarged logical analysis of actions. Thus, the actor can be conceived as having an intention with regard to what he is trying to do and this intention governs the non-representational subsidiary movements that do not themselves have conditions of satisfaction and that are caused by background abilities. The subsidiary movements are understood as intentional *through being governed by* the representational intention.

Should the above be the case, one may ask, as Dreyfus did, how intentionality is transformed into the movements. This is the same problem, which Merleau-Ponty addressed. His solution was that absorbed coping expresses another type of intentionality that he called *motor intentionality*. This kind of intentionality is typical for example in fluent playing of tennis, where the actor feels that the comportment is caused by the perceived conditions of action, not by ones volition, or urge. The actor feels that his body is regulated by the situation and it performs movements that feel *appropriate* rather than successful. The appropriateness of movements could be related to situational *conditions of improvement,* but are not related to the success of the end result of action.

Dreyfus maintained that if absorbed coping were reduced to the governance of movements via representational intentionality, as Searle proposed, its particular characteristics would be missed. Yet, absorbed coping appears to exist. Furthermore, Dreyfus provided evidence that there are many actions that do not have success conditions only conditions of improvement. He took an example of people learning to feel what is an appropriate distance to stand from one's fellows in a particular culture. Drawing from the existential phenomenology point of view of Merleau-Ponty, and from some recent results of neuroscience, he claimed that absorbed coping, or motor intentionality, does not need to be initiated by an intention. Therefore, absorbed coping could be seen as more basic than intentional action.

Dreyfus continued by changing his attention from individual action to collective intentionality. He argued that the phenomenological approach is needed in order to distinguish between the way a tension-reduction kind of collective intentionality produces social norms, and the way the representational kind of collective intentionality constitutes institutional facts. He maintained that the problem in Searle's logical analysis of institutional facts is that he merges institutional facts and social norms especially because he does not distinguish between motor and representational intentionality. Understanding the formation of social norms would, however, assume acknowledging motor intentionality and reduction of tension in the system. Dreyfus provided an example of the development of the use of money in society for elaborating this point. Practices of exchanging things must be developed before a medium of exchange can exist. Correspondingly, physical objects that are exchanged are not assigned value on the basis of collective representational intentionality, but on the basis of experience-based expectations of the use-values and the shared sense of what is an appropriate bargain in a specific situation (Dreyfus

2001). Thus, in a logically oriented analysis of the use of money it is easy to overlook the social norms that are already involved in exchange. Here Dreyfus also refers to Bourdieu, who considered that the pre-linguistic bodily understanding, *habitus*, continually "reactivates the sense objectified in institutions" (Bourdieu 1990). By analogy, as Järvilehto showed, in psychological stimulus-reaction tests the experimenter assumes erroneously that the response is caused by the stimulus, even though the very existence of the stimulus is result of the preceding organisation of the human-environment system and the practices of participating in the activity of a psychological test (Järvilehto 1998a).

In conclusion, Dreyfus claimed that there is a need for a richer ontology than the conventional distinction between individual subjects and natural objects, the environment:

"Absorbed coping and social norms have what he (Merleau-Ponty, LN) calls a third kind of being – a kind of being that is neither natural nor constituted, but is produced by the embodied intentionality that is always already present in the world of involved, active, social beings" (Dreyfus 2001, p. 23).

Societally embedded reasons rather than intentions explain action

Frederic Stoutland expressed corresponding concerns about intentionality. In agreement with Dreyfus he criticised the belief-desire model of reasons for action (Stoutland 2001, Stoutland 2002). He distinguished between *instrumental actions* and *responsive actions*. Instrumental actions refer to goal-directed actions, which assume awareness of the necessary means and ends. From a psychological perspective, desires and beliefs cause instrumental actions. These actions manifest Dreyfus' representational intentionality. In contrast to these, responsive actions, such as stopping at a traffic light, responding to knocking on doors, shaking hands, or responding to a computer screen, are experiential encountering of the situation or of the state of affairs in the world. People respond to them directly through perceiving, feeling, handling without deliberating or pausing. Responsive actions correspond to absorbed coping and are seen to be more fundamental than instrumental actions. In agreement with Dreyfus, Stoutland claimed that beliefs and desires play no role in responsive actions.

Although basically in agreement with Dreyfus, Stoutland, did not want to contrast instrumental action and responsive action. Stoutland maintains that not even instrumental actions can be adequately explained through the psychological belief-desire model. It is clear that there exist instrumental actions that are a matter of means and ends, and that they readily play an important role in our lives. However, from this does not necessarily follow that the reasons for performing instrumental actions would consist of the actor's psychological states, such as beliefs and desires rather than of what is the case in the practical realities.

Stoutland emphasised the concept of *reason* in explaining action, not intention as such. He continued that reasons, independently of whether being viewed from the perspective of normative reasons or from the perspective of explanatory reasons, are not instrumental. For example, in the normative case a person's stopping at a traffic light is less probably due to a belief or desire to stop than to understanding of the sign's meaning within the social system of traffic. Correspondingly, perceiving a sign is necessary for stopping at a sign but perceiving does not explain stopping. Instead, the existence of the stop sign explains stopping better. These explanations are not causal in the sense that the presence of the stop sign would cause drivers to stop as a general law. People stop because they accept the presence of the signs as a reason to stop, and they usually do so. Therefore, beliefs and desires are neither explanations nor causes. What are they then?

Stoutland claimed that belief and desires are *conditions* for something to be taken into account as a *reason* within the context of complex activity system, not reasons as such. The reasons for action are "states of affairs in the world, some of which we *experienced* as reasons and others of which we know to be reasons in other ways" (Stoutland 2001, Stoutland 2002). Thus, we may interpret that instrumental actions can be included as expressions of reason-based actions in which the individual's desires and beliefs are possible conditions that effect the taking into account of the state of affairs in the environment.

Stoutland's way of using the concept of reason links with von Wright's ideas in his later works. In contrast to his original theory of practical syllogism, in these writings von Wright substituted the notion of reason for the psychological conceptions of intention and belief as explanations of action (Kusch to appear, von Wright 1971, von Wright 1985, von Wright 1988). Von Wright defined a reason for acting as "anything to which the action is an adequate response". Thus understanding an individual's action is connecting it to a reason (von Wright 1998a). It is assumed that for something to be a reason for action the actor must understand its meaning.

The idea of adopting reasons as explanations of actions provides an alternative to the causal explanation of actions. Such an explanation is well suited to an ecological approach because action is not interpreted as being initiated or caused by an internal goal. The goal is understood as the way of working of the human-environment system that enables a particular outcome and creates possibilities for further adaptive action (Järvilehto 1994). Motor intentionality, or absorbed coping with situational conditions, is entailed in this notion of reason-based explanation of action (Dreyfus 2001).

Stoutland also pointed out that reasons as explanations of action are of a social kind that may not easily be imagined to form a structure of reasons in the absence of social collectives. "To be a reason is to be taken to be a reason by a collective" (Kusch to appear, p. 46). The societal embedding of the reasons within a larger system of activity appears to open up a connection with those perspectives that the cultural-historical theory of activity represents (Engeström 1987, Engeström 1999, Leont'ev 1978).

Differences in reasons for acting manifest themselves in people's ways of acting. Therefore the analysis of reasons, which are seen to be embedded in the societal activity, appears to provide a possibility to understand the construction of actions in particular situations, the target that we have formulated for the CTA methodology. In attempting to accomplish this we shall draw from von Wright's explications of the logic of the reason-based explanations.

The phenomenological theory that considers intentionality as a generic directedness of human mental phenomena and action, and that also extends intentionality to pre-reflective behaviour, is significant for our purposes because it provides a unitary basis for understanding human bodily and social behaviour in their interactions with the environment. Moreover, the phenomenological theory supports the identification of corresponding ideas within pragmatist semiotic concept of habit developed by Peirce, Mead and Dewey. Thus, the phenomenological theory appears to provide justification for the use of the concept of habit to express meaning and intentionality and to exploit the concept as a central theoretical notion in the development of empirical methods for the analysis of action.

3.2 Modeling activity systems

In the following we shall demonstrate the use of the cultural-historical theory of activity as a means to analyse actions in connection to their societal meaning. In addition we shall exploit the sociotechnical system analysis for providing a conception of the situational conditions of action that particular work domains afford.

Actions are not in strong sense planned

The line of thought within cognitive science that takes the situated action as its object critisized the instrumental interpretation of action in psychology (Suchman 1987). Suchman draws from ethnomethodology (Garfinkel 1967, Garfinkel & Sacks 1970) and attributes epistemic significance on the situated actions in understanding the dynamic organisation of action. Suchman writes:

"… instead of looking for a structure that is invariant across situations, we look for the processes whereby particular, uniquely constituted circumstances are systematically interpreted so as to render meaning shared and action accountably rational. Structure on this view, is an emergent product of situated action rather than its foundation" (Suchman 1987, p. 67).

The instrumental view to action expresses itself in the planning model of action. Plans are taken as sequences of actions designed to accomplish some preconceived end. According to this model plans are prerequisite and prescribe action in every detail. Communication is considered possible through common conventions of expressing intentions through plans. Suchman maintained, however that plans or other forms of internal representations, no matter how detailed or complex they may be, are not sufficient to explain the structure of real actions. The rich and unpredictable context requires to be accounted in understanding the constitution of the courses of action. Although systematic, actions are not in the strong sense planned. Plans could rather be interpreted as "weak resource for what is primarily *ad hoc* activity" (Suchman 1987, p. ix).

Actions are embedded in the cultural-historically-formed activity

The advocates of the ethnomethodical tradition were not the only critics of the instrumental interpretation of action. The cultural-historical theory of activity is another important methodology that takes distance from that point of view to action. The cultural-historical theory originates in classical German philosophy, in the writings of Marx and Engels, and in the Soviet-Russian cultural-historical psychology of Vygotski, Leont'ev and Luria. This theoretical orientation has in recent years become an international and multidisciplinary approach for the analysis of human conduct. Activity theory may philosophically be linked with other lines of thought that manifest the quest for overcoming the dualism's between idealism and materialism, mind and body, knowledge and skill. Activity theory has gained new discussion partners and allies from American pragmatism and Wittgenstein to ethnomethodology and theories of self-organising systems. (Engeström 1999, Engeström & Miettinen 1999) As we are interested in the dynamics of the actual construction of action in situations, we felt it necessary to draw connections between activity theory and phenomenology. The latter provided a philosophical basis for the understanding of situated actions by theorising about the ways we relate ourselves to reality and seize the meaning of the world (Heinämaa 2000, Merleau-Ponty 1986).

The concept of activity system that was developed by Engeström (1987) on the basis of the cultural-historical theory of activity offers what could be called an "*activity-system context"* for the analysis of action in empirical work analysis. Engeström focused on activity as a societal system (Engeström 1987). In his chapter in a recent joint book on "Perspectives on Activity Theory" Engeström defines activity as "an object-oriented and cultural formation that has its own structure" (Engeström 1999, p. 21).

The adoption of the activity system as the research object distinguishes Engeström's theory from most approaches in the social science literature. The majority of these adopt the notion of goal-directed individual action as their object of research (Frese & Sabini 1985, Hacker 1998, Hoc 1988, Rasmussen 1986, Vicente 1999, von Cranach & Harré 1982). In reference to the above-made philosophical distinction between the two types of intentionality, these theories deal with instrumental intentional actions. They focus on the sequential and hierarchical control of actions through internal goals. Thus, these approaches have theoretical difficulties to deal with the social and cultural aspects and meanings of action, and they are unable to manage with the determination of actions by the context.

The advocates of the cultural historical theory of activity agree with the ethnomethodological critique of the planning model of action. However, in the cultural-historical theory the societal and historical determinants of actions are emphasized (Engeström 1999). An activity-theoretical analysis is not restricted to the personal and individual meaning of actions but, instead, relates locally constructed actions to the material and societal reality that may be expressed in generic form in the structures of activity system (Engeström 2002). An activity theoretical analysis does not suffer from the problem of reducing action to an expression of individual intentionality because the object of analysis is the societal system of activity.

From mediated action to activity system

A.N. Leont'ev made a seminal contribution to the understanding of human conduct by developing the concept of activity (Leont'ev 1978, Leontjew 1973a, Leontjew 1973b). In his conception activity is understood as a system of relations:

"Activity is a molar, not an additive unit of the life of the physical, material subject. In a narrow sense, i.e. at the psychological level, it is a unit of life, mediated by psychic reflection, the real life function of which is that it orients the subject in the objective world. In other words, activity is not a reaction and not a totality of reactions but a system that has structure, its own internal transitions and transformations, its own development" (Leont'ev 1978, p. 50).

Leont'ev demonstrated the development of activity as a system and explained the emerging of psychological functions in the process in which the environment becomes an object to the human actor. Thus the evolution of human behaviour reflects the development of the objective content of activity. The concept of the object (target) of activity is central in the concept of activity. The constituting characteristic of activity is its objectivity (Leont'ev 1978) and the *object-directedness* is the basis of the intentionality of action.

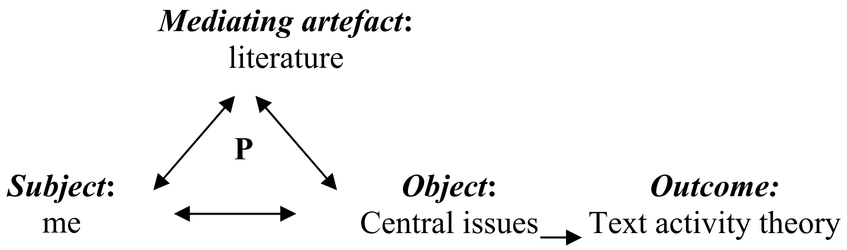
The idea of *mediation* is also central for the understanding of activity as a system. Via this notion activity theory overcomes the dichotomy between the environment and the person, and also between the individual and the social. Mediation is comprehended as the possibility for a human organism to create an auxiliary stimulus in his environment. These are material or symbolic artefacts that can be used as a way to control one's own behaviour. Vygotsky wrote:

"Because this auxiliary stimulus possesses the specific function of reverse action, it transfers the physiological operation to a higher and qualitatively new form and permits humans, by the aid of extrinsic stimuli, *to control their behaviour from the outside"* (Vygotsky 1978, p. 40).

It is neither the internal-personal, nor the external-environmental factors that are primary for the control of behaviour, but rather they both are included in the triangular structure of a social act. As material or symbolic artefacts acquire the controlling role in action they also become equipped with the function of carrying societal meanings.

The process of mediation was articulated by Vygotski in connection with individual action or action of a group of individuals in a situation. By making use of the societal conception of activity of Leont'ev (1978), Engeström extended the interpretation of the concept of mediation and invented the model of an activity system. (Engeström 1987). In a recent article Engeström described his theory by using an example of his own participation in the conference of activity theory (where the cited chapter was first read) (Engeström 1999).

Engeström started by first describing two successive actions in which he as a researcher might be involved. These were the preparation of a paper (P) and giving a talk (T) in the conference (see Figure 3). These actions could be modelled using the triadic model of Vygotsky including the subject, the object and the mediating artefacts of action as follows (Engeström 1999, p. 30).



and

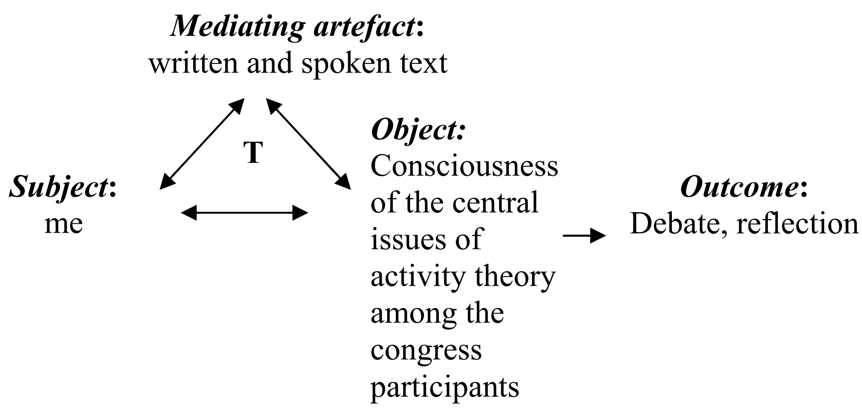


Figure 3. Individual actions of preparing a paper (P) and giving a talk (T) for a conference (Engeström 1999, p. 30).

Both these descriptions concerned particular individual actions. As we noted in the previous chapter in reference to Eskola (1999), it is usual in a psychological analysis to seek explanations for such perceivable and readily conceivable actions either from the personal or the environmental factors. These are then interpreted causally with regard to the dependent variables that represent the problem phenomena under investigation. As Eskola argued, a more realistic approach would consider the context of activity within which these actions take place, and start the analysis of action from there. However, the activity is not immediately perceivable, and it therefore needs conceptualisation. It would be necessary with the help of interviews and document analysis to create a meaningful context to that which is immediately perceived to be going on. Only against this context would the actions and the motives behind them become intelligible.

According to Engeström the context of action is the activity system. It can be modeled as a complex triangle that is an extension of the original Wygotskian triangle structure of an individual action. An activity system model is a tool to comprehend the various interactions within the system, and the tensions or contradictions in these interactions may also be indicated. Figure 4 provides an example of an activity system. The system may be understood to have developed from the original relationships between a subject, the community and the environment within which he lives (the centre triangle of Figure 4). These relationships have become increasingly mediated through the artefacts, rules and the division of labour. Thus, the artefacts mediate between the subject and the object, the rules between the subject and the community, and the division of labour between the community and the object. As a consequence, a modern activity system with a complex system of relations emerged. The figure demonstrates an activity called "the activity of international activity-theoretical collaboration" (Engeström 1999, p. 31).

As we may note, the activity system model of Engesteröm is not a mere illustration. Instead, it is grounded in the initial Wygotskian triadic conception of action. The elements of the system bear a theoretically definable relationship to each other. This is a major advantage compared to most models of complex sociotechnical systems, which typically only provide a descriptive list of elements of the system.

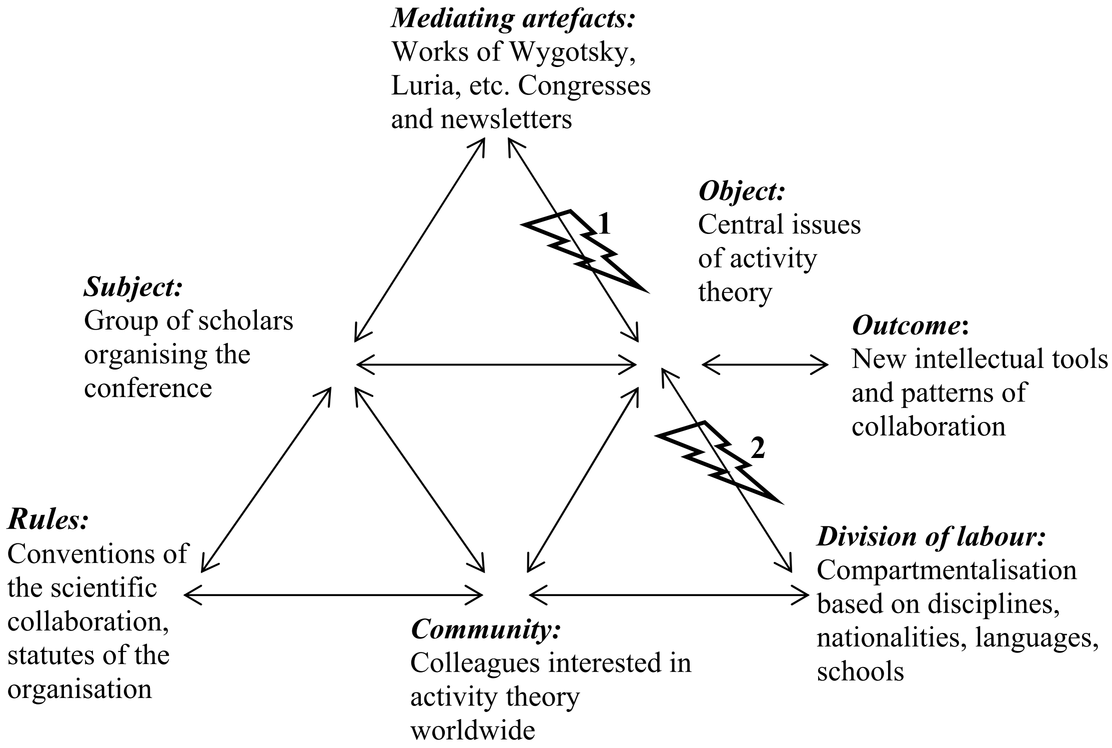


Figure 4. An activity-system model of the "activity of international activity-theoretical collaboration". The lightning-shaped arrows indicate two internal contradictions are indicated: one between the object and the mediating artefacts (1) and the other between the object and the division of labour (2) (Engeström 1999, p. 31).

The relationship between the object and the outcome of an activity is the actual process of activity. This may be comprehended by an analysis of various situated actions that constitute it. The actions share the societal system of activity not only as a common context, but even as a common object. As can be seen from the examples developed by Engeström (Figure 4), the objects of actions and activity are the same. The outcome of the activity, however, is not just situational and momentary; instead it is composed of results that are societally new and significant, objectified meanings and interactive practices.

The activity-system model is not static as it might appear at the first sight. The lightning-shaped arrows are used to refer to contradictions between elements and neighbouring activity systems. In the depicted example of the activity of the international activity-theoretical collaboration, Engeström distinguished two major contradictions: one between the object and the mediating artefacts (1) and the other between the object and the division of labour (2) (Engeström 1999). By drawing these arrows Engeström indicated that there exists a discrepancy between the very challenging object and the rather weak means available for collaboration, and another between the challenging issues and the fragmented division of labour that keeps pulling the different parties away from each other. From these examples of contradictions in this system, one may infer that the contradictions of the system create dynamics and pressure for change in it. Not depicted in this example are such possible contradictions that exist between the current activity system and another one, e.g. a system of education that as its outcome produces future subjects for the depicted activity.

Engeström also identified the contradiction that always exists between the presently dominant form of a particular activity and the new form that may be emerging within it. This raises up a final point that should be made in reference to the activity-system model. It concerns the historical perspective that the model entails. The currently available features of the system can be made conceivable only through a historical analysis of the activity system. Such an analysis provides the final basis for the evaluation of the appropriateness of particular actions in concrete situations. Enabling the conception of actions in a historical perspective is a significant achievement of the activity-system approach of Engeström (1987).

Activity cannot, however, be conceived without analysis of individual actions (Leont'ev 1978, p. 64). An important task for an empirical study, therefore, is to define concepts and means for the analysis of personal actions as they are embedded in the actual social and material context. The need for such an analysis was identified by the proponents of activity theory (Engeström & Miettinen 1999), but at its current stage the approach appears to suffer from the scarcity of such studies. This conclusion was also drawn by the authors of an informative essay review (Minnis & John-Steiner 2001) about of the recent book on activity theory (Engeström et al. 1999). These reviewers noted that instead of being treated as personal participants of actual transformations within activity systems, people are often interpreted generically in terms of their roles (Minnis & John-Steiner 2001). A corresponding observation gave us a further impulse for the theoretical work that is presented in this book.

3.3 Formative modeling of work domains

It was mentioned above that the activity theoretical work research that is based on Engeström’s theory should be enriched by analyses of the behaviour of personal individual actors and groups. Accomplishment of this aim assumes that actions are studied in real situations. This requires methods for modeling situations and for describing the conditions in the situations. Lack of such measures may be the underlying reason for the scarcity of analyses of personal actions and of their actual role in the transformations of activity systems. Our particular research interest is to understand the construction of action in DCU-environments. Therefore, we find it indispensable to develop means to model the objectives and constraints of different domains, and their expression in particular situations. In this section we shall consider approaches for such modeling. Thereafter we shall return to the problem of analysis of the construction of personal situated actions.

With reference to Rasmussen, Kim Vicente introduces a sociotechnical task analysis methodology. From this perspective it is usual to decompose the research object into structural elements of different levels. According to the decomposition method used by Vicente (Moray & Huey 1988, Rasmussen 1986, Vicente 1999) the technical or engineering system is considered to form the core, around and above which the workers, organisational and management infrastructures and finally the environment as a context are conceptualised. Rasmussen & Svedung differentiated even more levels through decomposing the environment further into company, regulators, associations and government (Rasmussen & Svedung 2000).

Each level of the system forms a particular behavioural process, which is modeled as a flow of events, tasks or decisions. The levels of the system coincide with the research areas of different scientific disciplines. Therefore, as Rasmussen and Svedung claimed, the processes on these different levels are in sociotechnical analyses usually studied independently of each other (Rasmussen & Svedung 2000). This, of course, violates the system-theoretical idea of mutual interaction between the elements and levels of the system. Further, because the levels are dealt with separately, the behavioural processes at each level are treated without the context and content provided by the other levels of the system.

The above mentioned difficulties were seen by Rasmussen and Svedung to be due to the deficiencies in the modeling concept normally used (Rasmussen & Svedung 2000). According to this concept the functioning of the system and also the performance of the human operators are comprehended from the point of view of causal sequences of events and decisions. Human errors that are frequently used as explanatory concepts for system failure are elements of the post hoc reconstructions of such sequences. In order to avoid the drawbacks of the sequential and causal modeling, both Rasmussen and, inspired by him, Vicente searched for more adequate concepts in the modeling. The basic solution that both identify is a functionally-oriented analysis of the domain (Rasmussen 1996, Vicente 1999).

3.4 Categorisation of task analysis approaches

Vicente developed an instructive description of earlier task analysis techniques (Vicente 1999). A major source that Vicente used for the description was the book by Kirwan and Ainsworth (1992), a comprehensive guide that included most of the published task analysis methods which were available at the time of writing of the book. Below we shall present an interpretation of Vicente's analysis of these techniques. Table 2 is our summary of his comparison of different task analysis methods. The table was constructed with the help of two basic categories. These are the *object of analysis* and the *type of modeling* used in the method.

With regard to the object of analysis Vicente distinguished between the task and the work domain. Moreover, as Table 2 indicates, within those analysis techniques that define the task as their object, a further important distinction may be made between the instruction-based and the constraint-based orientations. The other dimension of the table is the type of modeling. It includes the frequently mentioned two modeling approaches, normative and descriptive, and the third introduced by Vicente, the formative modeling.

In his book Vicente devoted much space to providing examples of different methods that are used in analysing work. In the description he also pointed out typical strengths and drawbacks of the different methods. We summarised these descriptions with the help of the above table and classified the different task analysis methods into the different cells. Thereby we defined the types of vocabularies that characterise the methods found in the cells. It appears that the various methods have problems in fulfilling the needs of analysis that the current DCU-work. These problems are due to deficiencies in the conceptualisation the object of analysis, and in the construction of a corresponding vocabulary.

By constructing Table 2 we wanted to emphasise the conceptual developments that Vicente and Rasmussen made in order to avoid the disadvantages of the standard modeling methods. The first important notion that promotes re-orientation in modeling is the concept of *constraint*. This concept helps to take distance from those methods that rely on an instruction-based conception of tasks. Such methods describe what ought to be done, and provide an ideal sequence of actions. An error is a deviation from such a sequence. Thus, a normative aim characterises these methods.

The vocabulary that is used in these methods is either oriented only to the input and output of the process, or also to specify, in a formal way, the steps between. As Vicente explained, the major drawbacks of these methods from the point of view of work design are that they underestimate the actors' creative inputs in the mastery of work, and that they leave only little room for variation in work performance. From this it follows, furthermore, that the methods do not appear to promote operators' learning. The applicability of these methods in the design of artefacts is restricted, because the methods pre-assume that the means used in the task are already specified.

Table 2. Categorisation of different task analysis methods (developed based on Vicente 1999.

Object of analysis / Type of modeling	Task: Instruction-based	Task: Constraint-based	Work domain
Normative	Defines what *should be done;* utilises an input-output or *sequential* approach and instrumental vocabulary	Defines tasks as what *should be avoided* in reaching the result; utilises an *event-oriented* sequential approach and instrumental vocabulary	
Descriptive		Describes *actual behaviours*; utilises *event-oriented* sequential approach and instrumental vocabulary; *constraints* emerge	
Formative			Defines outcome-critical *boundaries of action;* utilises vocabulary that orients toward *behaviour-shaping intrinsic work constraint*
=> Type of explanation	*Causal explanations* of *actual* realisations of performance		*Functional* explanations based on explicating the *potentials* of performance in a domain

When focusing on *constraints* the centre of interest changes from what *ought* to be done to what *should not* be done. Interestingly, by concentrating on the limitations of behaviour and the reduction of degrees of freedom, the constraint-oriented analysis highlights the existing possibilities for the actual realisation of the task. In this respect this type of method is better suited to the analysis of performance in open systems. However, these methods still focus on particular courses of events and describe action sequences. They conceive behaviour as separate, objectively definable events (errors, choices, and acts). Therefore, the explanatory power of the acquired results is limited. The alternative would be to conceive the object of analysis as a dynamic adaptive non-event.

The demand for conceiving action as dynamically constructed in situations appears to become fulfilled through a further type of task analysis. These methods are characterised as descriptive, because the analyses consist of careful elaboration of the courses of action when people perform complex tasks. Ethnomethodological analyses are typical descriptive constraint-oriented models. These analyses are informative sources for the identification of new constraints of actions, because they distinguish theoretically between the given task and action as performance that is constructed as an encountering between the actor and the environment in a situation. As Vicente noted, notwithstanding this re-orientation, behaviour is still typically described through conventional sequential vocabulary, the analyses are event-oriented and refer to particular courses of events. The conclusions are based on these descriptions, which restricts their usability in the design of new tools. The challenge, thus, is to develop a way to express generic requirements for artefacts in uses that do not yet exist. The object of analysis should thus be approached with such a vocabulary that comprehends generalities in the situated actions.

Causal and functional explanations of action in task analysis

We may infer that methods that define the task as their object of analysis all share a further underlying common feature. They are based on linear causal explanations of relations between structurally decomposed elements, such as the environment, the actors, and the tools (Rasmussen 1990, Rasmussen & Svedung 2000). This communality of task-oriented methods is expressed in the bottom of the Table 2. Rasmussen and Svedung pointed out the restricted validity of causal explanations in the case of complex phenomena of open sociotechnical systems. There are at least two reasons for this. Firstly, the elements of causal analysis are specified only to the level of detail that is known to the analyst in the given context. Moreover, counter examples can also be developed by small changes of the context. Due to these factors Rasmussen and Svedung concluded that:

> "A causal explanation is only valid to an audience, willing to generate the context that makes the explanation plausible, and the message then actually lies in this context." … "the elements of causal models, for instance the concept of an 'event', are elusive: the more accurate the definition of an event, the less is the probability that it is ever repeated. Completeness removes regularity" (Rasmussen & Svedung 2000, p. 30).

Thus, causal representation of the phenomena is proper and effective in many respects, but they are not adequate in the open systems with feedback functions. In these circumstances linear causal reasoning becomes circular. Rasmussen and Swedung considered this problem to be a generic deficiency of the methods used in cognitive science. Also Fahlbruch has identified the restrictions of causal analysis in understanding human behaviour in complex sociotechnical systems (Fahlbruch 2000). With reference to the earlier discussion of this chapter, we may add that intentional behaviour is in these analyses interpreted as instrumental goal-directed individual action. The validity of this conception as a generic model of action was shown to be questionable based on phenomenological arguments of the nature of human intentionality.

Another type of explanation is needed to complete causal reasoning in the analysis of the functioning of open systems. The suggestion is to use explanations which are based on functional abstraction (Rasmussen 1986, Rasmussen et al. 1994). According to this approach relational structures are defined in the studied phenomenon that connect quantitative variables (Rasmussen & Svedung 2000). The authors write that the structures represent practically isolated relationships, which are valid for a variety of systems, and they have long been considered an acceptable scientific representation of the phenomenon. The internal consistency of the relationships can be proved mathematically and tested empirically. This type of model is effective for understanding the basic mechanisms and to define limits for performance and conditions for desired outcome. Furthermore, functional modeling provides a common frame for engineering and human sciences because functions can also be interpreted, as Vicente does, as “A goal-relevant structural property of work domain. An affordance that is relevant to the purposes for which the work domain was designed“ (Vicente 1999, p. 7). Vicente makes here a clear, although not explicit reference to Gibson’s concept of affordance.

When adopting a functional way of explaining events the object of analysis will be transformed from tasks to *work domain.* We consider the concept of work domain to be the second central concept in Vicente’s task analysis (see Table 2). Work domain was defined as “the system being controlled, independent of any particular worker, automation, event, task, goal or interface” (Vicente 1999, p. 10). The author used the metaphor of a map for the work domain. By showing the lay of the land independently of any particular activity on that land, the map indicates the possibilities for action. These could be modelled using a vocabulary that is oriented towards the outcome-critical boundary conditions of actions. These are called *intrinsic work constraints* and they are behaviour shaping because they define the boundaries of action (Rasmussen & Pejtersen 1995, Rasmussen et al. 1994). Intrinsic work constraint is the third important concept in Vicente’s task analysis methodology.

Vicente, whose attempts are guided by his interest in using the work analysis for the design of systems, labeled his approach a *formative modeling* of the work domain. Formative modeling is the third type of modeling that is used in Table 2 to categorise task analysis techniques. By the term formative Vicente replaced the original term “predictive modeling” used by Rasmussen et al. (1994).

Specifying the nature of a formative task analysis

The formative approach to work makes use of functional explanations and focuses on intrinsic work constraints. As indicated above, these constraints are defined behaviour shaping because they determine the boundaries for action. Vicente maintained, furthermore, that the approach he advocates is based on an ecological approach. The method is qualified as ecological “because it gives precedence to the constraints that the work ecology imposes on goal-directed behaviour“ (Vicente 1999, p. 48). An ecological analysis should according to him “begin with, and be driven by an explicit analysis of the constraints that the environment imposes on action” (Vicente 1999 p. 55). The ecological approach is contrasted with the prevailing cognitivist approach, of which the information-processing approach is a good example. A cognitivist work analysis starts with and gives priority to cognitive constraints (Vicente 1999, p. 49).

We find the concept of intrinsic work constraints very important for the task analysis. This concept seems to be closely related to the concept of affordance by Gibson (1977). As we indicated earlier, the connection with Gibson is not elaborated by Vicente but the term affordance is used by him (Vicente 1999, p. 7). Assuming that it is correct to interpret the term in a Gibsonian sense, then the intrinsic work constraints could be understood as features of the environment that indicate the usefulness of the environment for some purpose of the actor. This seems to be the interpretation, which Vicente has in mind, because the intrinsic constraints are tied with the analysis of the outcome-critical functions of the system, and they are considered behaviour shaping.

Questions may, however, be raised concerning Vicente's interpretation of the notion "behaviour-shaping". Vicente maintained that the intrinsic constraints determine boundaries of action and through them shape behaviour. The idea of constraints determining boundaries that shape action easily transcends into a further idea that the constraints also determine behaviour, not only its boundaries. Of course this interpretation is against Vicente's deliberate attempt to design for adaptability. However, because there is no explication regarding how the actors, for their part, relate to the intrinsic constraints this idea of the determination of actions through the constraints may introduce into the method.

Vicente proceeded to distinguish two types of behaviour-shaping constraints, cognitive constraints and environmental constraints. Whereas with reference to Dewey and Bentley, he deliberately discussed the theoretical inadequacy of separating the two sources of explanation (Dewey & Bentley 1949, Vicente 1999, p. 47) he chose to accept this course of action. Moreover, he claimed that either of these sources of explanation could be preferred in analysis, but that an ecological analysis should start from environmental factors. He saw that a task analysis should start as an ecological approach and evolves into a cognitivist approach as the object of analysis proceeds to the personal variables. When analysing human behaviour the author does not take distance from the conventional cognitivist and objectivistic vocabulary.

Moreover, Vicente does not make any theoretical justification of the categories of the "behaviour-shaping constraints" which form the layers of the analysis. The categories were work domain, control task, strategies, social organisation and cooperation, and worker competencies (Rasmussen 1986, Rasmussen et al. 1994, Vicente 1999, p. 113). The categories appear arbitrary because Vicente simply listed them without providing any elaborated reasons for his choices.

Within a coherent ecological approach it should, of course, be possible to treat human action from an ecological point of view. Such a framework should be based on the idea of the unity of the two parts, as was indicated by Dewey and Bentley. A corresponding position was expressed by Tim Ingold. He proposed the following interpretation of ecological approach with which we fully agree:

"By contrast, a properly ecological approach, in my view, is one that treats the organism-in-its-environment not as the compound of internal and external factors but as one invisible totality. That totality is in effect, a developmental system, and ecology deals with the dynamics of such systems"(Ingold 2001, footnote 12).

Hence, there appear to be some theoretical inconsistencies in the basis of Vicente's cognitive task analysis as an ecological approach. When dealing with the work domain Vicente chose a functionally oriented approach but, unfortunately, human performance was interpreted in mechanistic-deterministic terms. Moreover, the structure of the sociotechnical system is not explicitly justified.

Connecting formative modeling with activity system modeling

Rasmussen and Svedung expressed corresponding critique against the prevailing structural decomposition of sociotechnical systems and the isolated cognitivist way of comprehending actions (Rasmussen & Svedung 2000). The authors basically identified the need for the concept of activity as the unit of analysis. However, they did not adopt the concept. Consequently, they did not develop any alternative to the cognitivist vocabulary that Vicente and they themselves use for the analysis of human performance.

It appears that Vicente tends to fall into the very trap of swinging between environmental and personal explanations of behaviour (Eskola 1999). According to Eskola this is the destiny of the mechanistic-deterministic paradigm in social science. This paradigm is related to a causal explanation. The alternative paradigm takes *activity* as its starting point. With the help of the concept of activity it is possible to connect the intrinsic constraints to the objectives of the activity and to understand the significance of theses constraints to local actions. Accomplishing inquiries concerning *how people take these constraints into account* would denote a change in the basis of explanation. Instead of relying merely on causal explanation the investigator would extend his repertory by adopting a reason-based explanation for analysis of human action.

Furthermore, the activity-system model would allow a conceptually coherent basis for identifying the elements of the sociotechnical system and it also defines their mutual relationships, which allows understanding tensions within the system and eventual pressures for change.

The activity-system approach of Engeström would open up a theoretically defensible alternative way to define the sociotechnical system and provide a conceptual basis for deriving the intrinsic constraints of the work domain. It would, furthermore, promote understanding of the emergence of these constraints and make explicit their connection to the societal motive and meaning of activity. The use of this frame would facilitate transcending the dualism between the social and technical, and also between person and environment, towards which Vicente's elegant concept of formative modeling already opens a way.

We also see that in order to avoid an objectivistic and deterministic point of view towards the sociotechnical system it should be necessary to distinguish deliberately between two different activity systems, the design activity and the operators' or the end-users' activity. The constraints of the domain must be taken into account by the actors of both activity systems, because they set boundaries for actions in both systems. The ways the boundaries are taken into account in either of these activity systems, by the designers or by the end-users, respectively, have an effect on the other activity system. These interactions could be analysed with help of the activity-system model of Engeström.

With the aim of defining the intrinsic work constraints from the point of view of the user, we suggest that a formative modeling of the constraints should be completed by an analysis that focuses on the actors' taking the boundaries into account in their actions. Thus the shaping of the performance could be seen as an active personal involvement of the subjects with their environment. We see that the activity-system analysis itself may tend to become objectivistic without such a deliberate attempt to take the end-users' point of view in the analysis of activity. The last column of the Table 3 indicates that a third object of analysis is necessary for the analysis of work.

We propose that an ecological work analysis should focus on both *domain* and *practices* and consider both in connection with the *activity system.* This extension is shown in Table 3. Practices may be conceptualised on the basis of the data acquired in a descriptive modeling of the task. Identifying practices represents a formative modeling approach that is characterised by an attempt to distinguish generic dispositional features of behaviour. Revealing the meaning of these practices requires that the practices be connected to the objectives of the activity system. The standards of excellence of behaviour may be defined by analysis of the internal good of practices (MacIntyre 1984) (see further in this chapter). The internal good is defined by a modeling the objectives and the constraints of the domain and analysing how people in their actual actions take into account these factors, i.e. what personal sense they make to them.

The modeling of practices represents a further type of explaining actions, the understanding explanations of action (von Wright 1998a). This extension of the modeling and analysis of actions should provide a solution to the problem mentioned by other authors that studies carried out from Engeström's activity system perspective are not grasping the agents of activity as personal actors (Minnis & John-Steiner 2001).

In conclusion, we see that the theory of Engeström provides an activity-system frame for the analysis of actions. This theory shares a system analytic perspective with the cognitive work analysis approach of Kim Vicente (1999). This common orientation gave rise to our attempt to draw connections between these two approaches and to use them in an integrated way in a new modeling approach. According to it, the generic intrinsic constraints and the situational conditions of actions are conceived and interpreted in the activity system context. The further justification for such an integrated use of the two concepts is that they share an ecological idea of the human-environment interaction and of the development of human action. The combination of these two approaches should strengthen the ecological perspective of the analysis of activity. The Core-Task Analysis is the attempt to achieve this integration.

Table 3. Extended categorisation of task analysis methods. The far right column introduces the extension of the methods by an analysis that focuses on practices that are analysed in an activity-system context.

Object of analysis / Type of modeling	Task		Core Task	
	Instruction-based	Constraint-based	Work domain	Practices
Normative	Defines what *should be done;* utilises an input-output or *sequential* approach and instrumental vocabulary	Defines tasks as what *should be avoided* in reaching the result; utilises an *event-oriented* sequential approach and instrumental vocabulary		
Descriptive		Describes *actual behaviours*; utilises *event-oriented* sequential approach and instrumental vocabulary; *constraints* emerge		Describes *actual behaviours;* different human-environment *interactions* are considered
Formative			Defines outcome-critical *boundaries of action;* utilises vocabulary that orients toward *behaviour-shaping intrinsic work constraint* within an *activity system*	Defines *habits and the standards of excellence* based on the *internal good of practice* using vocabulary that express meaning and sense within an *activity system*
=> Type of explanation	*Causal explanations* of *actual* realisations of performance		*Functional* explanations based on explicating the *potentials* of the domain for performance	*Understanding explanations* of actions based on clarifying the reasons for action with relation to *activity*

3.5 Analysis of actions from the point of view of their meaning

As indicated above, in the Core-Task Analysis, we intend to place the analysis of the constraints into a theoretically coherent activity-system frame. In this way we may facilitate understanding of the history and development of the constraints and enable comprehending the constraints in relation to the shared and meaningful objectives of the activity. Further, we aim to create means to analyse actions as personal engagement with the objectives and constraints of activity. In this section we shall develop a proposal how to analyse situated actions from an ecological point of view within the activity-systemic frame.

A.N. Leont'ev's theory of activity entails conceptual possibilities for an analysis of personal actions and their construction in particular situations as embedded in the societally structured systems of activity. In his work Activity, Consciousness, and Personality, published in 1975 in Russian, Leont'ev developed the theoretical conception of activity and introduced the concepts for the psychological analysis of personal action.

"And finally, the principal thing. The analysis of activity and individual consciousness is, of course, derived from the existence of real physical subjects. Initially, however, that is, *before* and *within* this analysis, the subject appears only as some kind of abstraction, a psychologically "unfulfilled" whole. Only as a result of the steps taken by the research does the subject disclose himself, concretely-psychologically, as a person. … For this reason it was necessary to introduce into this analysis such concepts as "partiality of consciousness" and "personal sense" (Leont'ev 1978, p. 95).

Meaning and personal sense

According to Leont'ev the object of activity is that part of the environment which may become an actual source of the fulfilment of human needs and, therefore, it forms the social *motivation* of activity (Leont'ev 1978). In his conception, motivation is not connected with the state of the individual as such, but rather with an object in the environment. Moreover, as other authors also have pointed out, human beings have created consciousness and the ability to distinguish between self and the environment through the sharing of the object with others, and via developing an ability to communicate about shared outcomes (Mead 1934). Thereby the world becomes objective to individuals. The objectivity of the world is expressed in that the environment becomes divided into parts that may become targets of need fulfilment and, thus, useful results for humans. These parts of the environment are organised as parts of the activity and therefore have meaning for the human beings (Järvilehto 1994). Consequently, "meanings are the most important formative elements of consciousness (Leont'ev 1978, p. 118).

Leont'ev made an important specification about his conception of meaning. He noted that although language serves as the carrier of meaning in the human community, it should not be taken as "a demiurge", a supreme creator.

"Behind linguistic meanings hide socially developed methods of actions (operations) in the process of which people change and perceive objective reality. In other words, meanings represent an ideal form of the existence of the objective world, its properties, connections, and relationships, disclosed by cooperative social practice, transformed and hidden in the material of language. For this reason meaning in themselves, that is, in abstraction form their functioning in individual consciousness, are not so "psychological" as socially recognised reality that lies behind them (Leont'ev 1978).

As generalisations of reality, often embodied in language, meanings are "objective-historical ideal phenomena" (Leont'ev 1978). However, such an objectivation of meanings tends to develop the conception, as if meanings would have an independent existence in the external world. This conception provokes the further distorted idea of the need for transmission and interpretation of meaning in consciousness, instead of conceiving the meaning as immediately present in an actor's practical engagement with the environment and in the organisation of the activity (Järvilehto 1994). Meanings constitute the way through which an individual may master the generalised human experience. The acquisition of the meaning takes place in practical operations.[1]

"When learning to accomplish particular actions a child appropriates corresponding operations. In meanings the operations manifest themselves in crystallised and idealised form (Järvilehto 1994, p. 120).

Leont'ev's conception of meaning reconciles him with the advocates of the ecological human-environment system approach, for example Gibson and Järvilehto[2]. However, Leont'ev does not explicitly develop the conception of affordance that in the ecological approach is seen to express the significance of the environmental features for the human, i.e. manifests their meaning. According to an ecological viewpoint meanings are thus concretely related to the features of environment and events, especially in the sense of how the environment may be used, how it is afforded (Järvilehto 1994, p. 185).

Through the historical division of labour, human *activity* becomes hierarchically structured. Thus, *goal-defined actions* and, further, *operations defined by the situational conditions*, emerge (Leont'ev 1978, pp. 91–106). With the formation of this hierarchical structure a further significant change takes place with regard to the functions of the object of activity. Originally, the object acquired a dual function in the regulation of activity. It served both to *motivate* and to *orient* activity. During the formation of the hierarchical structure of activity the object of activity preserves its motivating function, but the orienting function is transferred to the goals of action of individual persons or groups of people. Yet, because activity as a societal system only exists through the actions of individuals or groups of people, a dynamically important relationship between the object and the goal emerges. (Leont'ev 1978, pp. 122–132).

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[1] Georg Rückriem has recently theorised about the difference between the cultural historical theory of activity and media theory and the sociological system theory (e.g. Luhman) in their conception of transmitting meaning, which question has become increasingly important for understanding the role of information and communication technologies. In activity theory, meaning does not need mediation, or a medium, but is appropriated in action. Rückriem identified a need and theoretical possibilities to reconsider the concepts of tool in activity theory by establishing links to system theory. The reference to the concept of sense appears to enable importing of the concept of medium to activity theory and establish a link to media theory Rückriem, G. 2003. Tool or medium? The Meaning of Information and Telecommunication technology to Human Practice. A quest for Systemic Understanding of Activity Theory. In Invited talk at Toiminta 2003 -conference held in Kauniainen, Finland in December 2–3, 2003. http://www.iscar.org/fi/: University of Helsinki, Center for Activity Theory and Developmental Work Research.

[2] Järvilehto, T. 1994. Man and His Environment. Essentials of Systemic Psychology (in Finnish). Oulu: Pohjoinen. Järvilehto, however, interpreted (p. 98) that Leont'ev appears to hold the view that the development of psychic processes is fundamentally the result of reactions to the environment. According to Järvilehto, it appears that the two-system approach leads to inconsistencies in attempts to explain the transition to an active coping with the environment. According to the alternative one-system approach the organism has an ability to "grasp" the world with integrated afferent and efferent processes. These integrated processes are from the very beginning organised towards achieving a result and thus divide the environment into meaningful targets and means. Järvilehto, T. 1998a. The theory of organism-environment system (I). Description of the theory. Integrative Physiological and Behavioral Science 33:4, pp. 317–330, Uexküll, J.v. & Kriszat, G. 1932. Streifzüge durch die Umwelten von Tieren und Menschen. Frankfurt am Main: Fischer.

Under increasingly divided organisation of labour the societal meaning that is connected with the object tends to loose its immediate adequacy as a phenomenon of an individual consciousness. As the original connections with the material conditions and tools of work become remote, the societally formed meanings imbedded in them appear in two different forms for the individual, as what they are societally, and what they are for him or her. The point in this psychological duality of meaning is not that people, depending on contextual or personal features, would reflect the objective meanings more or less adequately. Instead these meanings have different grades of richness and different positions in the organisation of the consciousness and actions of the individuals. The possibility for different structuring relates to the actually distinguishable two functions of meanings. For the subject, meaning is both a societally existing object, and also a means for conceiving the world. Vygotsky elaborated the latter function of meaning through the analysis of the role of auxiliary stimuli, which that provide the possibility to control one's own actions from outside (Vygotsky 1978). In this function meanings have a role of psychological tools. They intertwine with the person's internal relations and individual forms of consciousness and take different positions in the organisation of the consciousness. Thus, in a psychological sense meaning appears in two phenomena. It is the shared and objective meaning, and simultaneously manifests another relationship, the *personal sense* that it as objective meaning makes to the subject. The inevitable subjectivity or partiality of conceiving the world is created through the personal sense (Leont'ev 1978, p. 122–128).

Personal sense expresses the relationship between the societal object-related motive of activity and the situated goals (Leont'ev 1978). Leont'ev maintained that in a psychological analysis of meaning the most important target is to study what sense the particular objectively definable meanings make for the person in his interactions with the environment.

"Meaning represents a reflection of reality independent of individual relation to it of each man; man finds an already ready, historically complex system of meanings and masters it in the same way that he masters implements of material carrier of meaning. A real psychological fact – a fact of my life – is that which I master with the given meaning, to what extent I master it, and what it becomes for me, for my personality. On what does the latter depend? It depends on what kind of sense the given meaning had for me (Leont'ev 1978, p. 170).

The subject's relationship with the societal meanings is thus the key tension in the personal action, and therefore, extremely important for the understanding of the construction of situated courses of actions. The problem for empirical research is how, in practice, to study personal sense and its constructive role in work.

3.6 The role habits in the development of practices

The basic idea of the method that we propose for the analysis of actions is to observe and inquire how people "master" the meanings relevant in reaching the outcomes of their work. Knowledge of this mastery is then used for explaining and predicting the construction of action in particular situations. By mastery we do not refer to the adequacy of conceiving objective meanings but, rather, to the position that these meanings as personal sense have in the organisation of actions. The adopted point of view indicates analysis of action from the point of view of *practice*.

Due to the role of meanings as mediators of interaction, people are normally not conscious of them but rather of the objects in the world. Meaning may, however, become conscious if attention is drawn to the meaning itself, instead of to its reference, the object. Meanings are manifested in the operations that the subject performs in the particular conditions of the environment. Thus, *by directing the actor's attention* to *the meanings that their operations convey*, it is possible to analyse how the actor masters the meanings in their particular actions.

This possibility of making the subject conscious of the meanings of his operations is based on the fact that meanings are reflections of reality, independently of an individual person's relationship to them. Correspondingly, affordances are material features of the environment and they have objectively meaningful usability independently of the particular subject's relationship to them. In this sense meanings and environmental affordances are *generals*. Therefore, they may be identified and analysed by an investigator who is knowledgeable of the context of action. The process and logics of the actor's taking affordances into account as meanings as he accomplishes particular operations may be interpreted as expression of the personal sense of these meanings to him or her.

Behind the above reasoning, there is the idea of Leont'ev that operations which are determined through their conditions, express meaning. This very idea can also be found in the pragmatist conception of meaning as habit (Kestenbaum 1977). It may even be stated that through interpreting the Leont'evian notion of operation from the point of view of meaning, which his text clearly allows, we approach the notion of habit developed by C.S. Peirce, G.H. Mead and J. Dewey.

The considerations above gave rise to our idea of applying the meaning-relationship model of Peirce for the analysis of action. This model provides the possibility to analyse operations from the point of view of their meaning and to identify the meanings in the texture of actual courses of actions in particular situations. The analyses are based on observational and interview material and focus on meanings as they operate in actual action of individuals. Therefore, we are dealing with meanings as personal sense, which are expressed in habits of action in particular situations. As we shall indicate later, the pragmatist conception of meaning enables conceiving meanings both as societal-generic and as personal-particular.

Another reason to draw from the pragmatist conception of habit is to strengthen the notion of the pre-reflective intentionality (absorbed coping) that we have found as a necessary ingredient in an ecological approach to action. We have interpreted Leont'ev to support indirectly a non-instrumental notion of intentionality and to acknowledge the fundamental role of embodied intentionality. As indicated above, Leont'ev criticised the idea that personal sense as a concretisation of meaning is a result of a deliberate process of giving meaning or of interpretation. The relationship is rather the opposite, personal sense becomes materialised in meanings, "It is not meanings that create personal sense, it is life itself" (Leont'ev 1978).

Our feeling is that inclusion of the concept of habit in the above described sense in the analysis of activity and situated action would also be agreeable to Leont'ev. This interpretation may be based on Leont'ev's own words. When outlining the possibilities of empirical analyses of personal sense of actions Leont'ev wrote:

”Incidentally the so-called practical psychology – that psychology which is nonscientifically used by the investigator, the writer, and the common man about whom they say that he ”understands people well” – is first of all a psychology of sense; its nonrecognised method is composed particularly of disclosing the sense of human actions. For this reason it is so personal, so concrete, and so genuinely vital” (Leont'ev 1978).

A scientific research method may readily have similarities with everyday reasoning concerning human behaviour. Revealing what sense events make for people is a powerful means for explaining people’s behaviour. In the above quotation Leont’ev referred to detective thinking. His observation offers a link to the theoretical ideas of Charles Peirce. One of Peirce’s central ideas was that habits have an inferential and abductive nature. Detective thinking is often characterised as a prototype of abduction.

What is habit and how is it constituted?

The concept of habit is widely used in everyday speech. The current dictionary of English gives the following meanings to this word: “A settled or regular tendency or practice, especially one that is hard to give up”; “addictive practice, especially one of taking drugs“; and, specifically in psychology, “automatic reaction to a specific situation” (Pearsall 1998).

As the dictionary definition indicates the everyday meaning of habit denotes routine or mannerism. This interpretation is legitimated by many scientists. “The whole term implies mechanical adaptation” (Alexander 1982, p. 108), as the Finnish expert on pragmatist Erkki Kilpinen quotes in his important recent work on the habitual conception of action in pragmatist theory (Kilpinen 2000, p. 57). Further scientific legitimisation of the lay conceptions is provided by the false equating of habits with automatized routines that are interpreted as shortened processing of learned, previously conscious sequences of actions.

The daily use of the word habit also reveals other connotations. In ordinary speech the term is used to refer to “my way” of doing something. In this case “habit” refers to a particular way of acting, by which the actor deliberately wants to distinguish himself from others. This version of the lay conception clearly hints to the idea of habit as carrying a message or meaning. This content of the term is connected with its function to indicate a practice that is customary to a group of people. The idea of a regular shared practice certainly also denotes control of action, but as the cited dictionary definition indicates, the control is typically seen to have a negative connotation of addiction. The concept of habit is also implicit in such terms as “ways or modes of working”, “best practices”, which are often used to describe the aimed results of work analysis. In these cases the aspect of control in habit has rather a positive connotation.

For John Dewey, one of the central figures of pragmatism, the concept of habit was the way to express the notion of meaning. The question of meaning “did seem to Dewey, to insinuate itself into every facet of the affairs of man” (Kestenbaum 1977, p. 2), and should, according to Dewey, be regarded as a central concept in philosophy. Kestenbaum (1977) was interested in intentionality in pragmatist thinking. He made the point that in Dewey’s notions of interaction and transaction there is an implicit well-developed conception of intentionality. Intentionality characterises the relationship between the subject and the object, or the self and the world, in any experienced situation. Intentionality is connected to the question of meaning that Dewey held to be the central aspect of human conduct. (Kestenbaum 1977, pp. 1–2). Dewey discussed meaning in a broader context than merely linguistic meaning and its relationships to knowledge claims or truth claims. A fundamental postulate of Dewey's theory of experience and theory of meaning is that meanings must be "had" before they can be "known".

What is really "in" experience extends much further than that which at any time is *known*. …
"The assumptions of "intellectualism" contradict the facts of what is primarily experienced. Things are objects to be treated, used, acted upon and with, enjoyed and endured, even more than things to be known. They are things *had* before they are things cognised" (Dewey 1958, pp. 20–21).

Dewey considered habit to operate on a pre-reflective level as an expression of pre-objective intentionality. Habits precede any sort of deliberate positing or specification of objects of knowledge or awareness. Even if meanings are not visible in the experienced situation, yet, they are present in every action. They are constitutive of the situation as it is experienced and had by the organism (Kestenbaum 1977, pp. 4–5). In coherence with this, Ingold also writes that having capacities to act in the environment does not indicate that these have evolved from structures that represent aspects of the world (Ingold 2001). Instead the human being is "a centre of awareness and agency whose processes *resonate* with those of the environment. Through such a pre-reflective capacity the agent is able to constitute objects of the environment. A corresponding point of view is taken by Bourdieu in his conception of habitus (Bourdieu 1990, Ingold 1996). In his account regarding Bourdieu's role in the development of the theory of habit Kilpinen writes:

"Intentionality without behavioural conditioning is empty, conditioning without intentionality is blind, - on this Bourdieu and the pragmatists seem to agree wholeheartedly" (Kilpinen 2000, p. 21).

There appears to be a connection between Dewey's conception of habit and the phenomenological conceptions of embodied intentionality, which we discussed in the beginning of this chapter. Elaborating such a familiarity between Dewey and phenomenological theory is the central theme in the above-referred work of Kestenbaum.

Dewey was, of course, aware of the traditional everyday meaning of habit. Therefore he explained elaborately why this concept still should be adopted into the conceptual arsenal of pragmatist theory of meaning and action. He maintained that there is a need for a word to express that kind of human activity, which is influenced by prior activity and in that sense *acquired*; which contains within itself a certain *ordering of minor elements* of action; which is *projective*, dynamic in quality, ready for overt manifestation; and finally which is *operative* in some *subdued form* even when not obviously dominating activity (Dewey 2002, pp. 40–41).

The above characterisation of habit may be interpreted to emphasise that habit enables continuity of human conduct through providing an adequate and adaptive structuring of the organism's interaction with the environment. It also stresses the pre-reflective way of working of the environment-organism interaction without necessarily an intellectual or conscious intention.

The structure of habit

The concept of habit is one of the important common concepts among the pragmatist theoreticians Dewey, Peirce and Mead (Kilpinen 2000). Charles Peirce developed the idea that as the expression of meaning, habit has a logical triadic structure. He conceptualised the structure in his meaning-relationship model (Peirce 1991) (Chapter 5). The model is usually depicted as shown below in Figure 5.

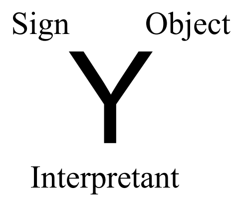

Figure 5. The meaning relationship model of Charles S. Peirce.

In this model of meaning, Peirce distinguishes the Object of the sign, its material carrier the Sign, and the Interpretant of the sign. The object is the “target” that the Sign refers to. The interpretant is the connection of the two into a relation to each other. According to Peirce it is a mediating representation that “fulfils the office of an intepreter” (Peirce 1991) (Chapter 3, p. 28). Peirce explained the meaning-relationship model and its function in the organisation of action to Lady Welby in the following way:

”But we may take a sign in so broad a sense that its interpretant is not a thought but an action or experience, or we may even so enlarge the meaning of sign that its interpretant is a mere quality of feeling. A Third is something, which brings a First in relation to a Second. A sign is a sort of Third.” …. “It appears to me that the essential function of a sign is to render inefficient relations efficient – not to set them into action, but to establish a habit or general rule whereby they will act on occasion” (Peirce 1958, p. 390)

At about the same time Peirce defined the sign in his article on pragmatism by saying:

”I will say that a sign is anything, of whatsoever mode of being, which mediates between an object and an interpretant; since it is both determined by the object *relatively to the interpretant*, and determines the interpretant *in reference to the object*, in suchwise as to cause the interpretant to be determined by the object through mediation of the sign” (Peirce 1998b, p. 410).

Through the establishing of signs it is possible to form meaningful habits that are usable in situations. Thus, for example, the sign of smoke denotes the object of danger of fire. The established habit is the connoted response of alarming the firemen to investigate the situation. This response is the interpretant of the sign. Significant is the idea of Peirce that the sign does not express its object but describes or otherwise indicates it. The interpretant is more deliberately determined by the sign (Peirce 1998b). Hence, the object must be reflected on as a possibility mediated by the interpretant.

Mead’s significant contribution to the concept of habit was to show that habit and its triadic structure originates in the social inter-relationships.

"The logical structure of meaning, we have seen, is to be found in the threefold relationship of gesture to adjustive response and to the resultant of the given social act. Response on the part of the second organism to a gesture of the first is the interpretation – and brings out the meaning – of that gesture as indicating the resultant of the social act which it initiates, and in which both organisms are thus involved. This threefold or triadic relation between gesture, adjustive response, and resultant of the social act which the gesture initiates is the basis of the meaning; for the existence of meaning depends upon the fact that the adjustive reaction of the second organism is directed toward the resultant of the given social act as initiated and indicated by the first organism. The basis of meaning is thus objectively there in social conduct, or in its relation to such conduct" (Mead 1934, p. 80).

The societal origin of habit elaborates the true sense of meaning. A meaning, or habit, has sense insofar as we, with the help of the emerging relationship mediated by the sign are able to regulate another person's behaviour through observing and regulating our own reactions to the sign. This reflective and controlling feature of habit identified by Mead with regard to social situations also applies in situations that do not seem to be social, as we shall see below.

Continuity and control in action through repetition and reflection

The pragmatist conception of habit is a difficult notion to grasp, not only due to the burden of its everyday mechanistic connotation but also because its content has changed and developed in the thinking of first Peirce, and later through the contributions of Mead and Dewey. With the help of the elaborate analysis of Kilpinen (2000) we shall in the following briefly outline the development of the concept. The different phases of the development manifest significant aspects of the concept and make intelligible its potential use in the empirical analysis of situated action.

The phases of development of the concept may be distinguished by analysing significant *transitions* in its content (Kilpinen 2000). The first phase could be characterised as the transition from the conventional understanding of habit as a pre-reflective corporeal phenomenon to emphasising it as a primarily mental and rational act. The second phase represents a transition that unites the rational mental content of habit with the workings of bodily operations. Finally, we may also observe an extension of the interpretation of the rationality of habit from a psychological to a logical sense.

From a mechanical to a rational habit. In Peirce's opinion, habituality and rationality are to be understood as mutually supportive aspects or modes of human action (Kilpinen 2000, p. 56). This conception of habit in Peirce's thinking refers to rational operations, not to "mere slothful repetition of what has been done". This conception is quite opposite to the conventional understanding of habit as a mechanistic routine and mannerism of operations.

Repetition is the sense of habit and expresses the corporeal existence of the organism in a world and in its striving for continued existence. Repetition must, however, be understood as repeating a way to set oneself into relationship to the world in a situation, not repeating an actual situationally specific operation. In this sense repetition indicates the idea of reflection.

The attempt at distancing from the traditional mechanistic conception of habit as mere repetition is welling up in Peirce's opposition to the Cartesian strict separation between body and mind. This tendency manifested itself in Peirce's considerations of the nature of inference. He maintained that all human thought has the quality of *inference.* However, inference may often be implicit. Inference is characterised by the struggle towards a *state of belief*. When the human organism is aware something that irritates it brings it into a *state of doubt*. This expresses itself in a process of inquiry that has familiarity with associations, where one thing suggests another. Such a suggestion is inference, or an ingredient of an inference. A rule of action, *a habit*, is established from this inference and a belief is realised. Peirce stressed the dynamic nature of the process of inference:

"since the belief is a rule of action, the application of which involves further doubt and further thought, at the same time that it is a stopping-place, it is also a new starting-place for thought" (Kilpinen 2000, p. 59, Peirce 1982, p. 263).

At this state of the development of the concept, habit was seen as a kind of induction and it was related to the act of drawing inference. Habit is the guiding principle in this process. According to Kilpinen this idea may be considered as the first hole in the wall that separates habit and rational action. Later the conception of rationality in habit was strengthened through the idea that rather than comprehending the human mind as "drawing" inferences one could see its functioning as having the characteristics of controlling and criticising. The inferences rather "fall" to us, but typically the human makes an effort to control his thinking.

The function of control as an ingredient of rationality gained in richness through the contributions of G.H. Mead. As indicated above, the possibility for control of behaviour through habit has its origin in the control of our own reactions with respect to the stimuli received from others, and also to those stimuli originated by ourselves. In each case intentionality and rationality resides in the controlling and responding phase of the conduct, not in an originating first intention by the "I" – aspect of the personality, as is the usual understanding of the question (Kilpinen 2000, p. 149).

From rational habit to a corporeal rational habit. If Peirce in the first phases of the development of the habit concept moved away from the conventional idea of habit as a corporeal repetition towards a conception of habit as rational action, he in the second transition of the notion of habit closed the circle. He namely extended the rational modes of habit to include the corporeal behaviour of the human actor. This turn in the conception is related to the further development of the notion of inference, and to the elaboration of its triadic structure. The required connection with rational and bodily actions was accomplished by exploiting the idea of an abductive process that has the character of a non-reflective creative act.

The core of the inferential process that moves continuously from the state of doubt to the state of belief is the process of abduction, the very leap to a new hypothesis. In real contexts of action abduction refers to the generation of a new hypothesis to explain unanticipated findings. From a psychological viewpoint abduction is closely related to instinctive action and guessing in our practical conduct.

"Now the mind acts in a way similar to this every time we acquire a power of coordinating reactions in a peculiar way, as in performing any act requiring skill" (Kilpinen 2000, p. 66).

The abductive reasoning deals with identifying new possibilities in the environment and, hence, it is in this sense creative and productive. The abductive suggestion comes like a flash and is an act of insight, in which already known elements become combined in a new way. Thus, the role of abductive reasoning is central in dealing with the contingencies of the world. At the same time, however, abduction is a weak form of inference that needs both deductive and inductive inferences for testing the insighted relationships between events (Paavola 1998 p. 213). An abductive hypothesis may be characterised by having the form "could it be that…?" Such an operation is the creation of meaningful connections to constitute habits. Thus, abduction is seen to be the way habit works. The other two forms of inference, deduction and induction, could be elaborated by saying that deduction means having a habit, induction not yet having it. The described structure of inference is claimed to be the general form of creating knowledge in action, corporeal or ideal. Peirce comes to the conclusion that the process of habit deals with the question of inference, and that "The question of pragmatism is the question of abduction" (Peirce 1998a).

The connecting of habit with abductive reasoning results in the possibility of considering both rationality and reflectiveness as inherent characteristics of habit. This is the central issue of pragmatism that Kilpinen deals with in his work. He writes:

"Almost any school of thought is aware of the extensive role of habit in human action, but it takes a pragmatist to maintain that this *supports* rather than obstructs the role of rationality in that process. Habit as cognised and reflected upon by the acting subject, not followed automatically like a routine, is the most peculiar feature in the pragmatistic conception of action." (Kilpinen 2000, p. 105).

Kestenbaum, who studied the pragmatist conception of habit from a phenomenological point of view, came to the same conclusion as Kilpinen. Kestenbaum considered that the most decisive feature of habit is that the reflectiveness is embedded in the repetition and continuity in the pre-reflective flow of action.

"The dramatic, creative meaning of habit, the human meaning of habit, simply cannot be grasped until its sense-making character is traced to its pre-reflective, pre-predicative foundation" (Kestenbaum 1977, p. 5).

This integration of apparently conflicting qualifications of habit is due to the fact that beyond repetition habit also has the function of carrying meaning. So much so that one may say that action is repeated because of the meaning.

This idea of reflectiveness in thinking is further developed by John Dewey in his theory of experimental or reflective thought and action (Dewey 1997). His significant contribution to the pragmatist analysis of thinking was the emphasis of the role of operative action, through which new solutions and knowledge are created. Mead was in full agreement with Dewey in stressing the unity of reflectiveness in practice by saying, "the man who uses the tools should also criticise the tools" because:

"Theory after all is nothing but consciousness of the way in which one adjusts his habits of working to meet the new situations. The man who has never made such readjustments is discouraged by the mere presence of the new situation" (Kilpinen 2000, p. 149, Petras 1968, pp. 55 and 57).

The reflectiveness that is inherent in the social act also qualifies the tool-using interaction with the environment. Thus, we may conclude that reflection and repetition are both inherent in habit, and, therefore, habit and reflection do not constitute exclusive ways of thinking (Kilpinen 2000). It is an empirical fact that reflectiveness may be more or less actualised in habit. The extent of the actualisation of this principle unity of reflection and routine in peoples' real actions may be analysed by constructing empirical criteria. These indicate differences in habits of action in respect to this underlying dimension. This idea is used further in the construction of empirical criteria for habits of action, as will be shown in later chapters.

Psychological and logical rationality of habit. The habit concept was developed to convey the idea of the rationality of action. Rationality was first used to refer to action in a psychological empirical sense. It was considered to express itself in the reflectivity and control of the on-going flow of actions. Repetition of habits characterised their rationality. The final phase of the development of the habit concept was marked with understanding habit as a logical structure in a more abstract sense.

Peirce was occupied with the question of the order of things in the world. He came to the general conclusion that *continuous change* is the general logic of the world (Kilpinen 2000). Because human beings have the aim to survive in the world through making sense of it, their living processes and reasoning must also manifest a processive and continuous organisation. He saw, further, that *generalisation* is the true aim of life, by which the necessary continuity in behaviour may be achieved. But how should generalisation be understood?

Peirce maintained that habits of thought and action yield continuity through generality. *Generality* in action expresses itself in its *interpretativeness* in a situation. The lack of interpretativeness in action leads to its *reactivity (Project 1998)*. For Peirce, action is rational as far as it is continuous and thus entrains the continuous change of the world. Thus, habits are rational. This he considered to be the logical significance of habit.

Peirce developed the conception of habit further so as to constitute a logical concept. He therefore distinguished deliberately between the concepts of habit and action. This was accomplished with the help of utilising the triadic semiotic model. In Peirce's own words

> ”The habit conjoined with the motive and the conditions has the action for its energetic interpretant; but action cannot be a logical interpretant, because it lacks generality.” (Hartshorne & Weiss 1935, Kilpinen 2000, p. 70).

This short definition comprises both the connection and also the distinction between the conceptions of habit and action. Kilpinen summarised his consideration of the development of Peirce's conception of habit by noting that "Insofar as there is rationality in the action-process, it is to be found in the habits that the particular actions exemplify" (Kilpinen 2000, p. 70). This conclusion of Kilpinen has significance for an empirical analysis of action: *the logic of action can be found in the analysis of specific actual operations or actions through identifying the habitual meaning that they manifest.* Adoption of this perspective in the analysis of real individual behaviour was the solution that allowed us to take distance from the instrumental concepts of purposeful action, motives, conditions and operations as the sufficient means to explain action. The rationality of actions is expressed in the continuity and generality, which the concept of habit may capture. As such, habit expresses a generic potential for action. Action refers to the actual behaviour that we may observe in a situated course of action.

Marja-Liisa Kakkuri-Knuuttila has drawn my attention to the fact that the ontology of the habit concept could be clarified with the help of the distinction Aristoteles makes between power (dynamis) that may be in a passive or an active state, and the actual consequence. Habit resembles dynamis, action its actualisation in a situation. (Kakkuri 2001)[3]. We interpret that the passive state of habit expresses the generic meaning, the active state is connected to personal sense and active habit i.e. habit of action. The remaining question is how to identify the habitual meanings and personal sense from empirical material of operations.

Empirical analysis of meaning in action – analysis of practices

The above-described characteristics of the concept of habit render the possibility to elaborate Leont'ev's activity model and accomplish categories for actual empirical analysis of the dynamics of action. Above we drew the conclusion that *habit* expresses both meaning and *personal sense* of actions within an activity. As was shown by Leont'ev, personal sense constitutes the relationship between the societal motive (meaning) of activity and the situational goal of action. Drawing on Leont'ev we use the concept of *orientation* to express the reflected and conceptually expressed connection between the motive and the goal in individual action, that has regulative role in the construction of actions.

Moreover, we see that personal sense becomes manifests via habit also in a corporeal and embodied way. We use the concept of *habit of action* that expresses personal sense in operative and corporeal form. In reference to the activity concept of Leont'ev, habit of action may be seen to express the relationship between the operational conditions and the goals of action in a situation. This concept denotes a learned principle in action that, in analogy to orientation, has a regulative role in the construction of action in a situation. Habit of action is identified by the way the subject takes into account and makes use of the situational conditions. Habit of action express personal sense, i.e. a subject's relationship to the societal meaning of activity, in an embodied way. As aspects of habit both orientation and habit of action express the potential characteristic of habit and denote a passive tendency or disposition to act. At the same time they may be interpreted in their active state as concrete psychological phenomena of action. The resulting realisation of habit is found in the resulting courses of action.

By using the habit concept in an empirical analysis of situated action we have proposed *a new way to analyse practices*. Even though we are interested in habits as repeated and generic ways of acting, our analysis cannot be based on observed repetition of operations as if repetition as such were an expression of the generality of these ways of acting. Our analysis does not start from empirically observed repetition

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[3] In his 4th Harvard lecture Peirce himself made a deliberate connection to Aristoteles in the above mentioned sense. Peirce, C.S. 1998c. The seven systems of metaphysics. In: The Peirce edition project. The essential Peirce. Selected Philosophical writings. Bloomington and Indianapolis: Indiana University Press. Pp. 179–195.

of operations but, instead, it finishes by determining orientations and habits of action as meaningful forms of action that provide continuity in action through repetition. Due to this order of reasoning it becomes possible in retrospect to identify generic ways of acting in a course of behaviour. This may be achieved by making use of interviews and recordings of particular courses of actions, as is usual in, for example, accident investigations or in simulator studies on the control of complex disturbance situations. Furthermore, we may also analyse peoples' conceptions of their work and the flow of an on-going normal action in real environments from the habitual point of view. In all these analyses both evaluations and also predictions concerning the appropriateness of actions in particular current or future circumstances may be made. The analyses reveal the potential in action for both learning and for mishaps.

Identifying a habits of action by analysis of possible and effective reasons

The methodical problem that we must solve is to identify meaning relationships in the operations of the particular courses of action, and we must find out what *sense* particular operations make for the actor. We proceed by conducting formative modeling of the domain to understand the objectives and intrinsic constraints of activity. We also inquire the accounts of the subjects. Thereby we identify the significance of observed operations with regard to the outcomes and the intrinsic constraints of the activity. We may ask what was understood as the meaningful *reason* for an action, i.e. for what the action was an adequate response. The arguments for believing that we thereby may reveal generic tendencies in action are drawn from Georg Henrik von Wright's philosophy of action.

As indicated in the beginning of this chapter the original theory of practical syllogism by von Wright (von Wright 1971) explained action on the basis of psychological states such as intention and belief. In his later work the basis of explanation was defined as reasons associated with adequate responses. Von Wright coined this way of explaining the "understanding explanation" to action (Kusch to appear, p. 27, von Wright 1985). "To understand and explain an individual action is to connect it to a reason"(Meggle & Von Wright 1995, p. 178). Von Wright distinguished between internal reasons, such as wants and desires that the person may find in him, and external reasons. The internal reasons correspond to the original premises of the practical syllogism. The external reasons are according to von Wright symbolic challenges, norms, rules and customs. He takes an example of the explanatory power of an external reason, by noting that one can explain his passing the salt to the person sitting next to him at the dinner table by mentioning that the other asked him for it. There is no need to back up this explanation by internal states of the person. All that can be said is that "this is the way one usually acts when there is no reason to do otherwise" (Meggle & Von Wright 1995, p. 192).

An important further aspect of the revised theory of action explanations of von Wright is that the "understanding action explanations" are not true or false statements about an independent reality (Kusch to appear, p. 33). Independent reality should, according to the interpretation of Von Wright's idea by Kusch, be understood as links between effective (or operative) reasons and particular actions. These links do not exist independently of acts of understanding, they are rather established in the acts of understanding. When someone takes a stand regarding his reasons “he builds a bridge, one might say, from his actions to his reasons. But his self-understanding is not purely ‘intellectual’. It is a kind of doing: A connection is created (von Wright 1995). I take Von Wright to describe here the working of a reflective habituality as it was described by Dewey and Mead as the actor’s consideration of his own habits. It expresses reflective habituality in the form of a retrospection in action.

When interpreting someone’s behaviour from outside it is possible to suggest further “understanding action explanations”. These are called possible reasons for action (von Wright 1998a). In our analyses of working actions, possible reasons may be suggested by domain-informed interpreters, who may take advantage of conceptualisations of the domain. In this way the activity-system analysis and the modeling of intrinsic constraints of the domain is made effective in the analysis of reasons. Analysis of the effective and possible reasons may be understood as describing the societal meaning of the action. When conducting analyses of actions with the help of identifying effective and possible reasons it is, however, important to take into account the priority of the self-understanding of the actor: “One cannot separate the truth about the connection between an action and the reasons from the understanding of this connection” (Kusch to appear, p. 32, von Wright 1981). Therefore the accounts of the actors must be the starting point of analyses of action (Harré & Gillet 1994).

The accounts given of actions reveal the personal sense of particular situated actions. In the method that we have developed for the analysis of meanings in action we make use of the principle of behavioural inference of reasons suggested by von Wright (1988, 1998a). In a nutshell this principle indicates that if persons understand the meaning of a particular sign as a (personal) reason for acting, this means that ordinarily the persons respond to the signs accordingly, unless they have overruling reasons against the action. This conceptual observation provides us with the possibility to create criteria for identifying, testing, and verifying whether a person masters a particular meaning or another. If we can define behaviours, the reasons of which the persons have understood we have identified habits of action and may assume that persons normally act accordingly. We utilise the meaning-relationship model of Peirce in revealing such structures in the observed courses of action.

Evaluation of practices

The reflection between effective and possible reasons opens up a possibility of evaluation of actions in the sense of exploiting what reasons have meaning in professional practice. In any activity there may be different parallel practices and culture the existence of which may be explained through the developmental perspective provided by the activity-system thinking.

In the evaluation of actions we also make use of the idea of Alasdair MacIntyre, according to which the basic human virtues are adopted in practices because the central goods themselves are the goods internal to particular practices (MacIntyre 1984). MacIntyre defines ‘practice’ as

> “any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realised in the course of trying to achieve those standards of excellence which are appropriate to, and partially definitive of, that form of activity, with the result that

human powers to achieve excellence, and human conceptions of the ends and goods involved, are systematically extended" (MacIntyre 1984, p. 187).

Our interest is clearly focused on actions that fulfil the above definition of practices. MacIntyre takes examples like chess or football playing, architecture, medicine, or some other socially practised skill. We are interested in defining the *internal good* and the standards of excellence of such practices, and we want to see how well these standards are fulfilled in the real actions that we study. MacIntyre maintains that practices and their internal goods are mutually defined within the action. There is also another type of goods that characterise practice. MacIntyre calls these *external goods*, because they are externally and contingently attached to the action. Examples of these goods are prestige, status or money. In our context various indicators of the adequacy of outcome of work or the amount of material products may be considered external criteria. These goods are achievable also by alternative ways. The goods internal to practice require involvement in the practice and they are only realisable within it through achieving the criteria of excellence that are necessary to maintain the activity. In this process the activity and its internal goods are continuously developing. MacIntyre maintains that the goods internal to practice may be personally adopted by participating in the process of practice.

"By subordinating ourselves in our relationship to other practitioners we have to learn to recognise what is due to whom; we have to be prepared to take whatever self-endangering risks are demanded along the way; and we have to listen carefully to what we are told about our own inadequacies and to reply with same carefulness for the facts" (MacIntyre 1984, p. 191).

The way of appropriating of practices is comprehended by MacIntyre resembles the ideas of Ingold regarding transformation of knowledge and skill that we referred earlier in this book (Ingold 1996, Ingold 2001). Also the currently widely used notions of "legitimate peripheral participation" (Lave & Wenger 1991) and "community of practice" (Wenger 1998) have close connections to the concept of practice proposed here.

We see that MacIntyre's conception of practice is compatible with the cultural-historical notion of activity as it emphasises the social and historical constitution of practices. We maintain, further, that the habit concept explains the way of working of the human-environment interaction. This concept has the power of comprehending meaning and the intentionality of action as both reflective and pre-reflective processes, and it provides a link between the notions of activity, action and operations of the cultural historical theory of activity and the ethnographically oriented conceptions of practice.

Our conception of practice thus indicates a coherent and complex form of socially established co-operative human activity that

- expresses the societal meaning of actions and, thus, is part of the culture of the community
- in contrast to actual actions manifests generic potentials to act
- is capable of realising goods that are internal to that activity and definable by analysing the objectives and outcome-critical functions of that activity, the core-task
- emerges and is transmitted in collaboration within a community of practice

- manifests intentionality of human conduct in the form of instrumental and reflective intentionality and in the form of absorbed coping or motor intentionality
- actualises the unity of skill and knowledge by its way of working which is characterised as reflective habituality
- enables an adaptive situated action in dynamic, complex and uncertain environments.

The Core-Task Analysis is the integrated methodology that we have developed to analyse practices by identifying the internal goods and the standards of excellence in particular actions through modeling the societal objectives and intrinsic constraints of activity and analysing their significance in the actual behaviour of actors. In later chapters we shall demonstrate the emerging and the use of the Core-Task Analysis method in empirical contexts.

3.7 Synthesis of the theoretical underpinnings: Core-Task Analysis

Our research work has been harnessed to formulate an empirical research method for the analysis of situated actions in DCU-environments. The approach should cohere with the methodological principles outlined in the previous chapter, and give rise to ecological understanding of human practice. The methodology should enable perceiving action as it develops within a human-environment system. The elements of this system should not be understood externally to each other. A further requirement for an ecological approach appeared to be to adopt a broad interpretation of human intentionality. This should acknowledge pre-reflective forms of behaviour, not only as another form of intentionality in addition to the instrumental or representational intentionality, but also as establishing the more fundamental form of intentionality. The phenomenological philosophy represents such an expanded conception of intentionality, and such a conception may also be traced in the pragmatist notion of practice. Reasons rather than intentions explain actions. Our claim, further, was that the idea of corporeal intentionality does not contradict the cultural-historical notion of activity and that the idea may is incorporated in the concept of operation.

We treated the cultural-historical theory of activity from two different perspectives. First we argued for the potential of the theory to create an activity system and developmental frame for the analysis of actions. The analysis of activity provides a possibility to understand what is the societal meaning of the studied work. We reasoned that this frame could be completed with another systemic frame, the functional modeling of sociotechnical systems. This frame has been developed for discovering the intrinsic constraints of work, which in a formative sense shape human behaviour. Such an extension of the original activity-system frame appeared to provide the necessary pre-requirements for an analysis of activity as a context of personal situated actions. The formative modeling facilitates analysis of the environmental features as affordances for the attainment of useful results.

The second perspective to the theory of activity was to draw from its conceptions of the development of human consciousness. According to Leont'ev the most important constituent of consciousness are the meanings. Through comprehending the evolution of human behaviour and its three-level structure, i.e. activity, actions and operations, the theory creates an understanding of the internal psychological dynamics of personal action. We interpreted that this dynamic consists of emerging of habits by which the actor expresses what personal sense the object of activity makes. Personal sense may be tackled in a psychological concrete form by scrutinising people's orientation to the object of activity and by analysing their habits of action, i.e. the ways of taking into account the constraints of the domain in their actual actions. The notion of personal sense provides the basis for the development of an empirical analysis of personal situated actions from a practice point of view. It also provides a conceptual connection between the cultural historical theory of activity and the pragmatist concept of habit.

We see that the pragmatist theory of habit complements activity theory through providing a model that may be used to analyse actions from the meaning point of view. Moreover, beyond explaining rationality of action in its psychological-particular sense, the conception of habit also offers a conceptualisation of the logical-general nature of human thinking. Rationality of habit expresses itself as generalisation through continuity that is the way of entraining with the continuous dynamic change of the environment. Thus, the notion of habit provides a basis for a conceptually elaborated comprehension of ”practice”.

The use the concept of habit allows distinguishing between the dispositional potential of the human to act and action as its situational realisation. The advantage of this distinction for the empirical analysis of action and determination of practices is the possibility to extract the habitual meanings as formative principles that both explain and predict the specific courses of action. For the accomplishment of the psychological-concrete analysis of habits the exploitation of the principle of behavioural inference of reasons was suggested. This principle is a crystallisation of the extended theory of action explanation. It was argued to be compatible with the pragmatist meaning-relation model and usable for defining habits of action as expressions of habitual meaning, i.e. understanding the personal sense of actions. Inquiry of orientation provides a further, indispensable mean of elaborating personal sense by informing of the actors' conceptions of the objectives of activity.

Entailments from divergent sources were drawn together to form the desired ecological approach to situated action. This approach was labelled the Core-Task Analysis. It is an approach that aims at understanding the development of practices. We have analysed the philosophical underpinnings of the theories that we considered necessary regarding this aim, and merged them into a whole. The conceptual ingredients of this theoretical approach are depicted in the following model (Figure6). It summarises our understanding of the situated construction of action within an activity system.

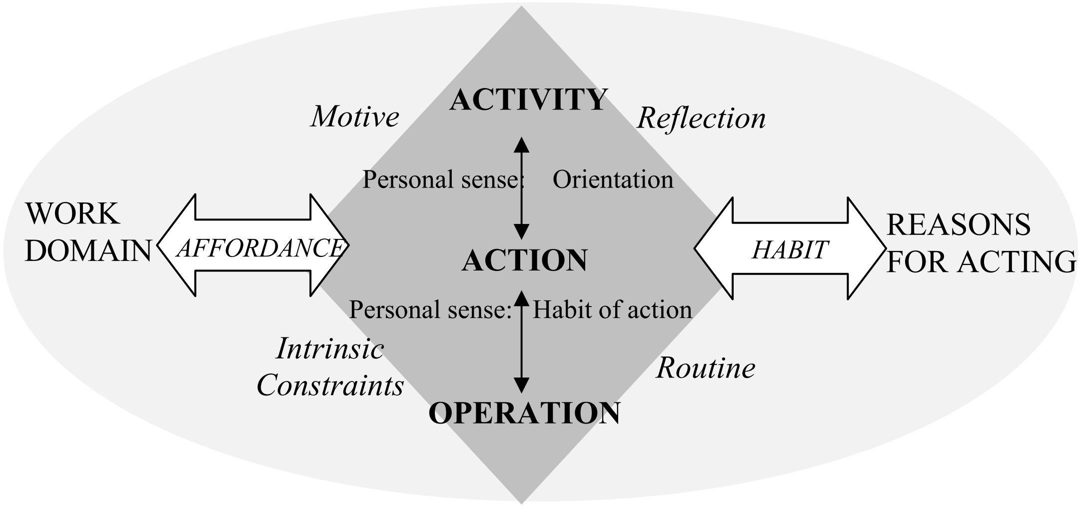

Figure 6. The conceptual model of the Core-Task Analysis. The human-environment interaction is characterised by affordances and habits. Both express the meaning of the interaction. Meaning is reflected in personal sense and it energizes action. Personal sense may be identified in peoples' conceptual orientation and habits of action that emerge in the interactions between the hierarchical levels of activity.

The concepts that are placed in the diamond-shaped field in the centre of Figure 6 the three central notions activity, action and operations that refer to human conduct as a psychological-concrete phenomenon. The other field of concepts represented in Figure 6 by the lighter oval is comprised of generalities that express the potential within the environment and within the human actor to form a meaningful and active functioning human-environment system that is realised in actual courses of action. Both the potential and actual aspects of action are realities of the world. In "orientation" and "habit of action", notions that express personal sense, the potential is in an active state and explains the dynamics of particular situated courses of action. Figure 6 defines our conception of practice and what conceptual components are necessary to understand the development of practices by the Core-Task Analysis frame.

The conceptual model of the Core-Task Analysis did not exist when the empirical analyses of working activities in the dynamic, complex and uncertain environments were started. In the forthcoming chapters we describe the emergence and use of these concepts in empirical studies of action in DCU-environments. By accomplishing this we shall transform the above model of the research object into a further model of a method for its analysis.

PART II:
The emerging of the new method:
The Core-Task Analysis

4. Disturbance orientation as an expression of expertise in modern manufacturing work

A field study in manufacturing industry provided the first possibility to start developing the new research methodology. A major technological change was planned in a plant that produced tooth gears for diesel engines for tractors. The traditional manufacturing shop was planned to be transformed into a flexible manufacturing system (FMS). The research was designed to facilitate the reorganisation of the work and to support re-training of the operators of the shop. The investigators conceived the change process as a parallel "top-down" determination of the functions of the system through design, planning and managerial decisions, and a "bottom-up" process of personal choices of the operators. The assumption was that the "bottom-up" definition of the role of the operators takes place in the undefined "grey zone" that the disturbances occurring in the system create through demanding diagnostic and operative responses from the operators. In the study we conceptualised the qualification demands and described empirically the role of the operators in the construction of the new FMS system during its implementation.

4.1 Orienting to the core task

Context-conditioned variability in an open system is difficult to anticipate in design or in formulating prescriptions for how to use the system. Due to this, enhancement of the situated adaptability of the system during its operations is a necessity. Vicente suggested the formative design concept as one possibility for the enhancement of adaptability into such systems (Vicente 1999). In a study of the implementation of a new flexible manufacturing system we approached the problem of context-conditioned variability from another, complementary angle. We focused on the operating personnel and studied the possibilities to enhance the adaptability of the system through developing the ways of operating it.

Creating adaptive operations is a contradictory issue. Because it is not possible to define exactly what actions operators should take in problem situations, the operators must be equipped with means to handle problems according to the situational needs. At the same time, there must be control over the validity of the means and measures taken. The latter is necessary for maintaining a shared awareness among all actors about the functioning of the system, and for ruling out unwanted and often latent side effects of actions. The demand for balancing between improvisation and control in the task performance creates a need to consider how we understand the concept of task.

Leont'ev defines a *task* as the given *goal* of action in *particular circumstances*. Being connected to the goal, "task" refers to the content of action, and it is primarily determined through the *conditions of attaining the result* (Leont'ev 1978). The relevance of particular conditions to the result may be expressed with the concept of intrinsic work constraints (Vicente 1999). These constraints are not specific for a particular situation but characterise the outcome-critical boundaries of action. Therefore, these conditions may be connected not only the situated goals but also to the objectives or purposes of the activity. We elaborate the Leont'evian conception of task by establishing the connection between the goals and objectives by Vicente's definition of intrinsic constraints. Consequently, we define a following conception of the core task:

Core task is such content of work, characterised through the objectives and the outcome-critical intrinsic constraints of activity, that the actor should take into account in all situations when determining the relevance of situated goals and conditions for the attainment of aimed objectives. [4].

We suggest that the dilemma in the operational coping with contextual contingencies of open systems could be solved through promoting the abilities of the actors to take into account the outcome-critical intrinsic constraints and the objectives of the activity in their particular situated actions, i.e. through orienting towards the core task.

The objectives and the outcome-critical constraints of the task are not necessarily overt in everyday work, because the daily working situations do not actually challenge the critical boundaries of appropriate action. Operators may therefore have a tendency to make shortcuts and rely on practices that usually work. Moreover, the core task also changes. For example, the introduction of ICT solutions into the control of work processes increases co-operative and interpretative demands in the maintaining of the optimal functioning of the system. For these reasons, it is far from self-evident that the operators know the content of the core task. However, because the core task deals with the objectives of the activity and the outcome-critical constraints of the system, the operators' understanding of the core task clearly has an effect on the optimisation of the functioning of the system.

First analysis of the operators' understanding of the core task

In the FMS study we tested possibilities to identify the operators' understanding of the core task through observing and interviewing operators in their normal work. We needed new concepts for developing a method to identify the operators' ways of framing the task. We became captured by the idea included in the cultural-historical conception of activity that emphasises the *orienting role of the goal* in action. This orienting role of the goal is seen to be due to the fact that the *personal definition of the goal of action expresses a person's stance with relation to the object of activity*

[4] The concept of core task has evolved during the many years of empirical work during which I have been in collaboration with several colleagues and co-authors at the Technical Research Centre of Finland: Norros, L. 1998. Evaluation and development of process operators' working practices. Presented at The Finnish Research Program on Reactor Safety 1995–1998. Final Symposium., Espoo. Pp. 187–198. Norros, L. & Nuutinen, M. 2002. The Core-Task Concept as a Tool to Analyse Working Practices. In: N. Boreham, M. Fischer & R. Samurcay (eds.). WHOLE. Reiman, T. & Norros, L. 2002. Regulatory Culture: Balancing the Different Demands on the Regulatory Practice in Nuclear Industry. In: A.R. Hale, A. Hopkins & B. Kirwan (eds.). Changing Regulation – Controlling Hazards in Society. Elsevier. Norros, L. & Savioja, P. 2004. Modelling of the activity system – development of an evaluation method for integrated system validation. Presented at Enlarged Halden Programme Group Meeting, Sandefjord, C2.9.1–12. An important contribution in emphasising the societal activity system connection of the core-task concept was made by my colleagues who study organisational culture: Oedewald, P. & Reiman, T. 2003. Core task modeling in cultural assessment: A case study in nuclear power plant maintenance. Cognition, Technology & Work 5, pp. 283–293.

(Leont'ev 1978, Norros 1989a, Norros 1995). Galperin used the term orientation to refer to a subject's cognitive, motivational and volative reactions to the task to be solved, or to a situation to be mastered. He stated, moreover, that "Most important in life is to orient adequately in a situation that demands action, and to direct one's actions properly" (Galperin 1979. p. 93). In this citation Galperin expressed the regulatory role of the framing of the task, which idea we then exploited in the construction of our empirical method.

The situated goal of action is constrained through the features of the situation. These are evaluated by the actors with regard to their relevance to the attainment of the desired result that is connected to the objectives of the activity. From the cognitive point of view this evaluation denotes the process of making judgements regarding the constraints, which process is regulated by the personal stance with relation to the object of activity in the situation, orientation. Thus, in making a judgement about what to do in a situation in order to attain the object/outcome, a person perceives the situation in a broader and more general context both in the cognitive and the emotional sense. Therefore, we were not interested in making explicit the linear mental processes of judgement, the goal that cognitive theories of judgement usually deal with (Dowie & Elstein 1988, Hoc et al. 1995, Schaafstal et al. 2000).

Instead, we theorised about determination of the content of judgements in the societal context of activity, and attempted to understand the regulatory role of framing of the situation from this more global perspective. We understood judgement as the construction of a relationship between the particular situation and its general culturally produced motivation and meaning. Support for this conception was found from the Russian philosopher Ewald Iljenkov (1977), who in reference to Immanuel Kant wrote:

"Understanding is an ability to relate general "truths", both elementary and most noble ones, adopted in the cultural process with situations that occur in real life and are thus non-repeating, unpredictable, unanticipated" …. "Understanding can be defined as the ability of a person to make judgements regarding particular facts on the basis of the general culture he has adopted" (Ilyenkov 1977, Ilyenkov 1984, pp. 22 and 33, translation from Finnish LN).

We interpreted Iljenkov by stating that judgement has two necessary characteristics (Norros 1988). Firstly, judgement refers to a personal construction of knowledge in a situation and it manifests itself as an ability to act in the situation. Judgement also includes the idea that a particular situation is interpreted by the actor within a generalised culture, forms of which have been adopted through the actor's own earlier experience or in deliberate formalised learning.

Guided by the above-mentioned theoretical ideas we considered *orientation* as *a personal stance with relation to the object of activity as it appears in the framing of the goals of situated action.* As an epistemic attitude, orientation regulates the evaluation of the conditions of the situation from the point of view of attainment of the goal. This regulatory effect may be identified in the way the operators take into account the result critical constraints of activity and its objectives in the situation, in other words in the way they define the core task in action. Thus, *orientation becomes evident in the personal definition of the core task.*

Taking the core task into account does not merely include the idea of knowing what the core task is in general terms. More importantly, it implies that operators are able to *judge* the various situations they encounter *in terms of the core task*. This provides them with the possibility to act in a given situation, which is the sign of expertise in the task (Norros 1995, Norros & Nuutinen 2002, Schön 1988). This conception was used in the development of the empirical method described in the following section.

4.2 Disturbance orientation: an empirical way to analyse the operators' definition of the core task

Our interest was to understand industrial developmental processes from a sociotechnical perspective. In particular we aimed at clarifying how technology takes its concrete shape through use, and is therefore influenced by the choices of the users. Our research group was multidisciplinary, consisting of two engineers, a sociologist and a psychologist (Toikka et al. 1990). We postulated that the development process takes the form of an interaction between the top-down design work and managerial actions, and the bottom-up operating actions of the users of the system. This interaction is particularly intensive during the implementation phase of the system. The idea was to use the concept of orientation as the basis for analysing the operators' reactions to disturbances that occurred during the implementation. Disturbances were considered as events that reveal the fragility of the system. The potential informativeness of the disturbances for the study of action is that the reactions to disturbances reveal concretely how the actors conceive the core task.

The study was carried out in a machining shop producing toothed wheels for diesel engines. In this shop the traditional production process and organisation was to be substituted for a medium-sized flexible manufacturing system (FMS). The new system was composed of four robotised NC-cells, a tempering plant, automated storage lift and the central computer system that controlled the functioning of the system. A skill-based organisation was created with six highly and homogeneously skilled operators (2 per shift) and one foreman, an engineer and expert in FMS-technology. We followed up the implementation of the system until it had clearly reached the stage of normal operation, which in this case took as long as 15 months. Another 18 months later, a further intensive follow-up was carried out to provide information about the status of the new production process when it had reached stable operation.

4.3 Disturbances as the "grey zone" between design and operations

In the beginning of the study we constructed comprehensive activity-systemic, and further functional and sequential process models, in order to conceptualise the then still existing old production system. The new production system under implementation was also modeled (Norros et al. 1989). We paid special attention to the changes in the functions and their technical and organisational realisations. The models provided understanding of the constraints of the transition from the old to the new form of production. The models were also used as tools in a model-based training programme that the investigators carried out at the plant. Both all the operators and foremen, and some invited experts from the design department, participated in the training sessions and thus contributed to the formulation of the models (Hyötyläinen 2000, Norros et al. 1989).

During the study, we became interested in the role of disturbances in the transition from the old to the new production. The disturbances were interpreted as forming a concrete intersection of the top-down and bottom-up processes. In this function disturbances both threaten the designed functioning of the system and simultaneously also provide possibilities to develop the system. The question we raised was whether, and under which conditions the disturbances can also function as a spring-board for the development of the operators' expertise (Norros 1996).

The orthodox model of system disturbance

In the conceptualisation of the role of disturbances in the development of a system we started with an orthodox model of system disturbances which is widely used in the field of industrial safety control (Hale & Glendon 1987, Kjellen 1987). The model can be depicted in a generalised form as shown in Figure 7. It draws from the system-theoretical idea that disturbances represent deviations of the system's normal functioning. For example, human errors may be included as an element of such a model, and human error models provide conceptualisations of possible causes of deviations. Other causes include equipment failures and design failures; to name the typical categories used to classify the cause of deviations. The deviation is interpreted as a threat to the functioning of the system. The feedback is conceived as the possibility of eliminating this deviation. Possible improvements in the system's predisposing condition are top-down effects from the design (Norros 1996).

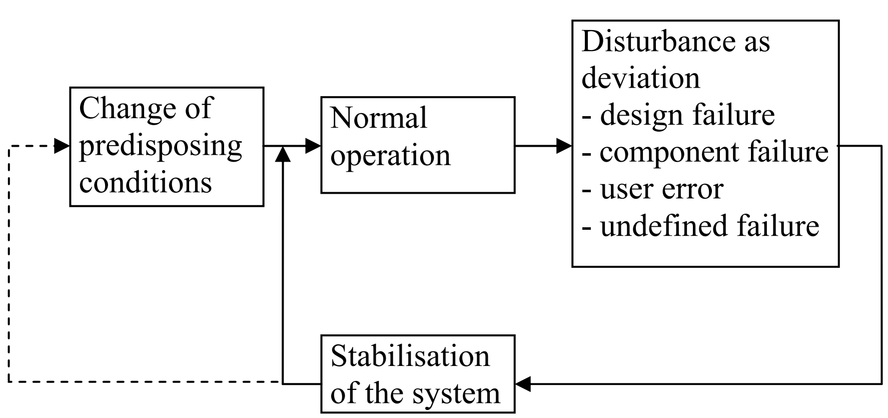

Figure 7. Orthodox model of system disturbances.

A general reduction of disturbance rate as a function of time can be predicted on the basis of the orthodox model. More precisely, a U-shaped "bath-tub" curve is to be expected with a high disturbance rate during implementation, a steady low rate in operation due to the feedback control of disturbances, and an acceleration of disturbance rate due to normal wear during later years of production.

Disturbance data was collected from the machining shop both during the implementation phase and later in the operation phase when the system could be considered to have reached a state of stable normal operation. During the implementation period the operators themselves kept logbooks about disturbances, and they were asked to note each novel disturbance by describing it and making an assumption about its cause. Because repeating failures were not registered, direct information of the disturbance rate is not available for the implementation period, but failure types may be analysed. During the operation phase, after 18 months of operation, a 24 hour intensive observation was made in the plant, during which all disturbances were registered and described by the researchers (Norros 1996, Toikka et al. 1990).

The *rate of disturbances* was one indicator of the functioning of the system. During the operation phase the rate of disturbance was 3 disturbances per hour, and the time needed for disturbance control was 25% of the total 24 hours observed. Even though data on failure rates during implementation were not available, and therefore the possibility to follow the development of the failure rate was lacking, the high rate in the operation phase was considered as counter-evidence to the "bath-tub" expectations. The scrutinising of the *failure types*, which was the other indicator of the functioning of the system revealed that the failure profile was very consistent in the implementation and operation. Such a consistency of the profiles and the nature of the profiles themselves contradict predictions of the disturbance model in several respects. First, whereas a high proportion of design failures is expected in the implementation, an equal frequency of these failures after one and-a-half years of full operation was surprising and not in accordance with the predictions of a bathtub curve. Getting rid of the "children's diseases" should take place much earlier. Second, the rate of failures that could not be defined – a typical situation in the beginning – was still very high in the operation period. Finally, the level of component failures was also high, although a slight reduction in the implementation phase was observable. Normally, we would assume that the component failure rate would increase through wear only after a considerable time of operation (Norros 1996).

We interpreted the result as evidence of the context condition variability of the rather complex system. The *failures do not speak of failures in the design but of the principle limitations of design* (Norros 1996, Toikka et al. 1990). We concluded furthermore:

"Given that the data support the assumption of the unpredictability of a complex system and the existence of disturbances as the more or less "normal" state of the system, *it would further imply that there exists pressure on and opportunities for the users to develop the system during operation, i.e. disturbances should also be taken into account as bases for innovation and change*" (Norros 1996, p. 164).

A new hypothesis was thus formulated that the operators do play a more or less deliberate constructive or design role in operating the system. At this point, we had the possibility to proceed at least in two complementary directions in the verification of this hypothesis. One was to concentrate on the analysis of the design process in order to demonstrate the demand for a user-centred approach for improving the design. One of the engineers of the team followed this path (Hyötyläinen 2000). The work of Vicente may be interpreted to correspond with this research strategy (Vicente 1999). Our own research interests were directed towards conducting a more detailed analysis of the operators' actions in the described situations in order to determine how the operators actually reacted to the disturbances. This strategy was used to identify possible design-like actions within the users' normal working practices.

4.4 Operators' disturbance orientations

As indicated above the disturbance rate in normal operations was observed to be high and, consequently, much time was needed for disturbance handling. However, considerable differences between operators were found with respect to how much they were personally involved with disturbance handling. The time spent for disturbance handling ranged from 0% to 47% of each operator's available working time. This variance was not due to differences in the prescribed tasks. On the contrary, the target of a so-called skill-based conception had been adopted in the design, which aims at homogenous skills and division of labour in the machine shop. The result demonstrates that disturbances threaten the system functions and that there are differences in responses to this threat.

The next task was to clarify what the differences in responses to disturbances indicated. On the basis of the theoretical reasoning referred to in the beginning of the chapter we formulated the hypothesis that the different responses indicate the operators' personal framing of the task and reflect different ways of comprehending the object of activity. Because the thus evidenced epistemic attitude, orientation, became overt in relation to disturbances we labelled it disturbance orientation (Norros 1989a, Norros 1996).

We used two basic criteria for conceptualising the differences in responses to disturbances. The first criterion was the framing of the *object of disturbance handling* in the situation. The decisive distinction was whether the disturbance is handled locally as a temporary deviation of normal functioning, or globally, including some *diagnosis* of the problem and feedback to the system in its normal state. The second criterion deals with how the operator frames his *own agency in the cooperative context of work.* Thus, it deals with the cooperative aspect of disturbance handling. It expresses participation in the shared construction of new knowledge in the disturbance situation. The emerging optional orientations are summarised in a decision-tree model depicted in Figure 8. The decision tree is constructed in a bottom-up direction, which is somewhat unconventional. It should, however, denote the users' point of view to tackling the "grey zone" of system development.

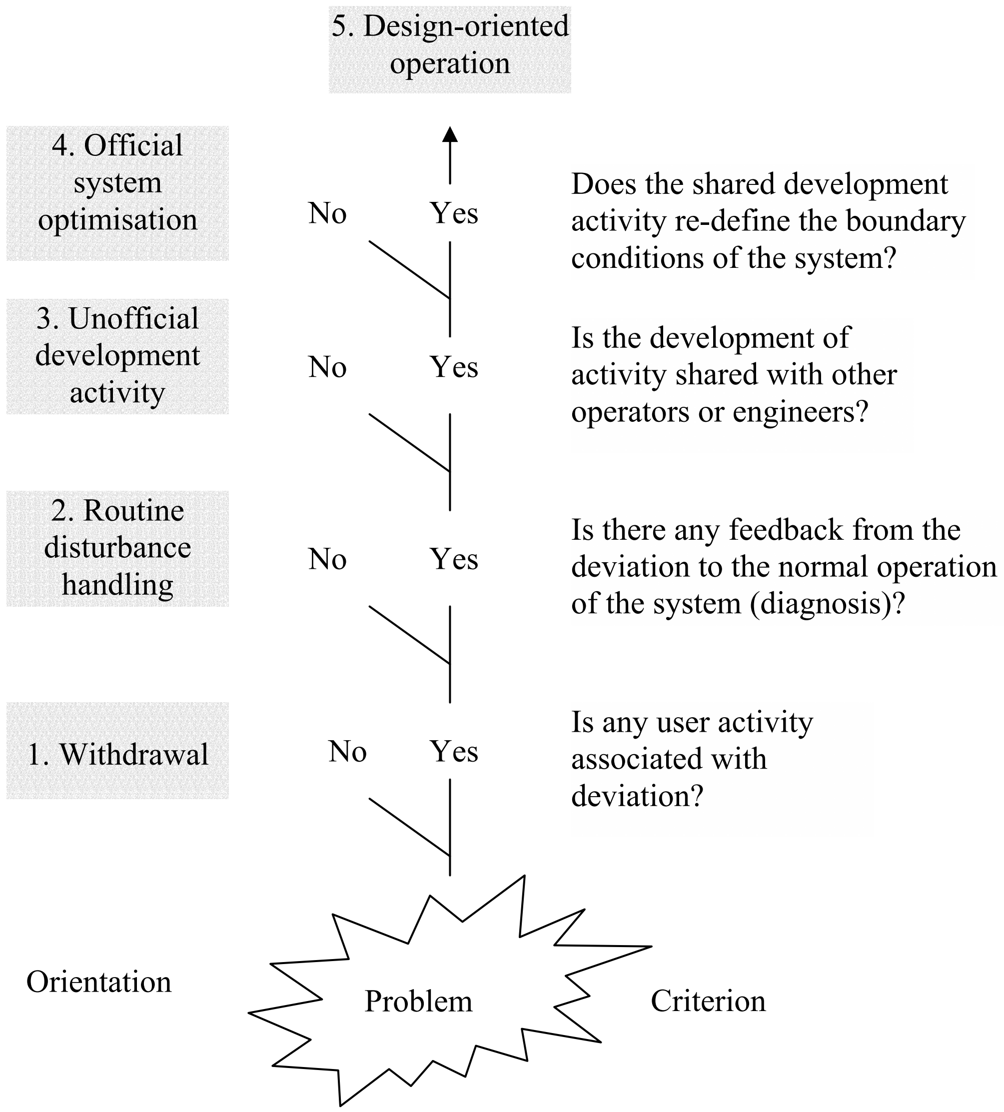

Figure 8. A decision-tree model of operational disturbance orientations. The criteria for decision are depicted on the right, the emerging disturbance orientations on the left.

In order to avoid an abstract definition of the different orientations we shall first demonstrate the emergence of the optional responses from the material. The example is presented in Table 4. The example of a problem solving action stems from our data collected during the intensive observation of the functioning of the FNS in the operating phase (Toikka et al. 1990).

Table 4. Example of the material from which the optional disturbance orientations were drawn.

Phase 1. Routine problem solving

At 22.33 one of the two operators notices a disturbance in the machining cell. The robot is placing the work piece inadequately into the mandrel of the machine and the machine stops. The operator removes the slanted work piece, resets the machine manually and updates the status information in the robot control. The time used for troubleshooting is 2 minutes. The user remains by the robot for the next operating sequence in order to check whether the disturbance repeats. It does not and the operator moves on to other tasks.

The disturbance was handled as a simple, rapid routine without diagnosis of its cause. At first, this seems to be sufficient. At 22:51 the disturbance reappears. The above routine is used to tackle it. This is repeated again three times at 22:52, 23:07 and 23:18.

Phase 2. First diagnosis: dislocated sensor element

At 23:36 the disturbance occurs for the sixth time. The operators are loading work pieces on pallets and they both go immediately to the place of disturbance. Meanwhile, as they routinely eliminate the disturbance, they also discuss its cause and optional methods of tackling it. Thus, a first diagnosis is formulated.

Having finished loading the pallet at 23:59 the first operator starts to work on the disturbance according to the first diagnosis. He adjusts a particular sensor element that is assumed to be dislocated and to have caused the problem. This appears to help but then the disturbance occurs again at 00:30.

Phase 3. Second diagnosis: Fault in robot control

As a reaction to the further disturbance, a new diagnosis is formulated and a new procedure to tackle the problem is started. This time the operator makes small adjustments to the robot program to change the robot trajectory. This is carried out in several phases interlaced with other tasks.

At 01:10 the above changes in the trajectory lead to a new disturbance, i.e. the work piece slips out from the robot's grip. Further adjustments in the program are made and the disturbance is eliminated.

Phase 4. Third diagnosis: Fault in the mandrel

The operator starts to investigate more thoroughly how the work piece is placed into the mandrel. He makes several manual moves of the work piece and notices that it has a tendency to become stuck in the mandrel from its lower part. He then assumes that there is a burr in the mandrel that prevents the work piece from becoming placed adequately. He grinds it with sandpaper. This seems to help until the disturbance reappears again at 3:30 and 3:38.

Phase 5. Stabilisation of the second diagnosis and final elimination of the disturbance

The disturbance has occurred 13 times. After carrying out other tasks the operator turns to the robot to make some adjustments into the program. He is now convinced of the adequacy of his diagnosis that the problem lies in the program and he spends much more time than earlier to tackle the problem. After 30 minutes of work he believes he has succeeded in eliminating the problem. This appears to be the case, since the problem does not reappear during the following 10 hours of observation.

At 04.24 the operator had struggled with the problem for almost six hours and used one hour and 23 minutes of his working time. (Norros 1996, Toikka et al. 1990, pp. 63–64).

The examples presented in Table 4 and further data from our study demonstrate the different optional orientations in a disturbance situation, expressly a situation demanding action. The descriptions in the following will make it evident that whereas actions in a disturbance situation are individual personal responses to the situation, the different orientations also manifest and are formed under both bottom-up and top-down constraints of the production. These also give rise to pressure to change orientation.

1. Withdrawal from disturbance handling

This orientation refers to the possibility that an operator does not make any attempt to handle the disturbance. Work is thus restricted to control of the normal functioning of the system. This orientation may be a result of learning the task as a deterministic sequence of actions through instructions or mere trial-and-error acquisition of the functioning of the system. Of course this is a rather extreme orientation that, when it occurs may also express workers' active resistance, or an attempt to short-term efficiency in work. This orientation may also be a result of Tayloristic division of tasks and organisational principles, or managerial cost sparing through use of narrowly qualified personnel. The top-down limits to this orientation are met when the restricted capabilities of the personnel gain sufficient economic weight. The bottom-up limits rise from the meaninglessness of this orientation from the users' point of view.

In our study this orientation was thought to be ruled out, as the aim was to create a skill-based production organisation. However, during the course of implementation the production constraints hampered the realisation of the rotation of work that was foreseen as the means to qualify the personnel equally. These constraints resulted in cumulatively increasing differences in the level of expertise between individual operators. The differences became overt in the above-mentioned wide variation between individuals with regard to the time they devoted to disturbance handling.

2. Routine disturbance handling

This orientation reflects a conception of work as carrying out pre-described tasks. Handling of anticipated disturbances with the instructed routines is included within the tasks. The operator reacts to disturbances one by one, locally without searching for any general explanation or systemic connection between them. Because the models of the system are formed in repeating situations through a repeating procedure, there is a tendency for the responses to become over-deterministic. The restrictedness and event-orientedness of the models of the system become evident when confronting more complex and novel problem situations. This orientation can be considered as a minimum level in advanced work but, based on what has been said of the demands for adaptability in open systems, it would be deficient in DCU-environments.

The previous example of our data demonstrated the dynamics of this orientation. Routine orientation seemed to be prevailing in the beginning of the problem solving, but repetition of the problem increased pressure to change the orientation. The attempt to diagnose the problem, facilitated by interaction with a colleague, was a sign of a shift to a further orientation. Thus we see that repetition, whereas it may result in a deterministic routine, also includes the possibility for reflection that results in development.

3. Unofficial development activity

This orientation is characterised through an attempt to diagnose the cause of the problem. The local problem is connected to its systemic context. Problem solving requires reflecting on and redefining the constraints and the goals of the action. The user is privately taking the authority of defining his task, thus adopting the role of the foreman. With regard to the system he is taking the role of a designer. Paradoxically, this secret developmental work maintains the traditional division of labour between operation and design by often preventing, through remaining covert, the revealing of the design limitations. By the same token, the operator is personally taking responsibility the effects of the solutions. In the worst case the personal solution may lead to further problems in the system. This is, of course, the reason why operators in complex systems are advised to maintain their role as mere operators. Thus, there is a conflict that creates the need for public and co-operative development activity. Should this challenge be taken by the managers, an explicit developmental strategy for enhancing adaptation would become necessary.

4. Official system optimisation

This orientation refers to a cooperative action of developing the functioning of the system within the prevailing boundary conditions. From the users' or operators' point of view this orientation requires preserving the disturbance as a problem and object beyond the actual situation. It also requires explicit knowledge of the system and other resources for development work. This kind of orientation has been the target in the humanisation of work conceptions and in the original sociotechnical experiments. The top-down condition for transcending to this orientation is that the management allows more autonomy for workers for motivational reasons or for making better use of the tacit knowledge of the users.

5. Design-oriented operation (system development)

In this orientation development activity is not restricted to optimisation of the system functions within the given conditions of the system. In the case that the development of the system becomes an economic and functional necessity for the production, managerial decisions are needed for creating institutionalised frames for continuous development activities. In such a situation systematic collection of operational experience that is fed back into the development of the structure, functional principles, and organisation of the system would be required from the operators. Acting in this role assumes that users adopt conceptual tools and systematic experimental practices that require institutionalised forms of interaction with design. Such an interaction with the users also demands new practices in the design, which sets forth the major top-down constraint to this orientation.

In our study an extensive evaluation of the operators' orientation could be accomplished in the normal operation phase on the basis of the data obtained during the 24-h observations and adjacent process-tracing interviews. Further data was acquired in interviews with the operators that took place three weeks after the intensive observation. In the interviews we used the observation material to provide specific points for reflection. We classified all the data systematically according to the orientation model. Using the existence of diagnosis of the cause of the disturbance as the criterion for determining the basic orientation, we obtained the result that 67% of the disturbances were handled in a routine way. In 33% of the disturbances a more advanced orientation was evident. Due to the cross sectional nature of the data, it was not possible to verify systematically whether these cases were handled as optimisation tasks. According to our definition, verification of the existence of this further orientation would have required that the operators would have continued working on the problem after the actual situation was over.

Unfortunately, the post-observation interviews did not provide systematic answer to the above-mentioned question. The top-down prerequisites for such orientation were available in theory, because the accepted organisational concept acknowledged such developmental work in the operators' task description. Further interviews concerning the operation phase in more general terms revealed 16 separate development activities, which according to the operators were optimising activities and to a great extent not connected directly to disturbances. Two of these projects could be evaluated to satisfy the criteria of the design oriented operation, as the design bases for the system were challenged, e.g. evident bottlenecks in the system were identified as being removable through a realisable redesign of the central control system. Unfortunately these actions and the identified possibilities for development did not result in appropriate managerial decisions. Later the possibilities for development work were reduced even more as the engineer, who had been acting as the foreman and expert in FMS technologies was moved to another position in the company.

Extension of the orthodox disturbance-model

We could conclude that the unanticipated contingencies of the system in operation create disturbances not only in the implementation but also in the operation stage of the production. The result also revealed that the users of the system play a central role in adapting the system functions to the unanticipated constraints of use, not only in the form of situational disturbance handling but also in optimisation, or even direct design activity. The bottom-up design activity spans over particular situations and continues after implementation in the operation phase of the production. These results exceed the predictions of the orthodox disturbance model, and call for re-formulation of the traditional model of system disturbances.

The extended model is depicted in Figure 9. The first enlargement of the model deals with the re-interpretation of the role of disturbances: Instead of conceiving disturbances as deviations they should be understood as expression of normal context-conditioned variability.

Second, the role of operators in a disturbance process should be recognised. In the original model their role is neglected. In reality, however, without the operators' actions disturbances would provide only very little feedback to the construction of the system. In the new model the role of operators is made explicit. Further, thirdly, the model takes into account the fact that the orientation of the operators is a significant determinant of the extension of the feedback from disturbances. As we demonstrated, orientation is a result not only of individual choices but also of the intrinsic constraints and possibilities of the production process. These are usually regulated through managerial and design actions as top-down determinants of the orientation.

The operators' actions also change the interpretation of the disturbance causes. This effect is indicated through the upward arrow in the disturbance box in Figure 9. When the intention is to improve design, every failure is a "design failure" in the sense that it becomes an object of design actions. Having adopted a design interest a person's attention is focused on the intrinsic constraints of the system as functional boundaries of the system. This kind of orientation denotes that the users have adopted a formative approach to the system.

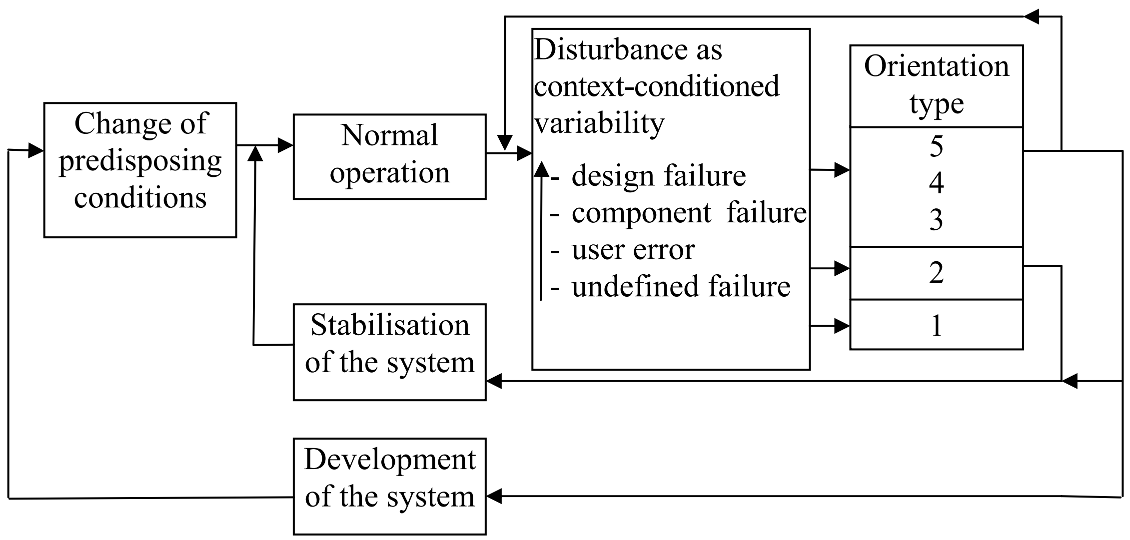

Figure 9. Extended model of system disturbances as springboards of development.

We may state further that the FMS study supports the validity of the approach of Vicente by making it evident that a formative approach may exist even in operation, insofar that sufficient top-down organisational decisions and bottom-up worker orientations are available. Moreover, it may be noted that the extended empirically based model of system development through disturbance is in accordance with the double-loop model for organisational development suggested by Argyris (1990).

4.5 Conclusions with regard to the development of the ecological approach to situated actions

The FMS-study was our first major empirical attempt to take distance from the traditional cognitivist approach and to develop a contextual and ecologically oriented methodology for the analysis of action. The empirical results of the study allow some conclusion regarding our understanding of action in DCU-situations. Further conclusions relate to the development of the methodology.

Disturbance orientation expresses a person's identity as an agent in a situation demanding action and his personal stance towards the object of activity as it appears in the framing of the situational goal. In a societal perspective the disturbance orientations may be interpreted as generalised approaches to the intrinsic demands of the task, to the core-task. These optional approaches represent societal forms of diagnostic judgement, the historical, societal and organisational development conditions of which were analysed in the study. Credit for the correct emphasis on the societal nature of diagnostic judgement goes to the sociologist of the research group, Kari Toikka. As a result the *existence* of different *practices* in a diagnostic task were identified.

With regard to the different forms of practice we developed the hypothesis that the disturbance orientation that a particular person manifests may simultaneously reflect the *developmental potential of his expertise* in this task. This hypothesis is based on the fact that orientation is a person's relationship to the task, not merely an actualisation of action under certain environmental and personal conditions, among them the amount of experience. Therefore, it may be assumed that corresponding divergence of orientations could be identifiable among both beginners and more experienced actors (Norros 1995). Moreover, because the content of the relationship relates to the subject's agency in creating knowledge in a situation, orientation expresses the potential of the subject to develop in the interaction with the environment. We may infer that development of expertise would be stronger in those individuals whose disturbance orientation exceeds the routine disturbance handling because they see developmental possibilities in the situation. The differences in orientation could possibly explain the observation that mere experience does not result in learning (Brehmer 1980).

In the FMS study we did not analyse individual persons' judgements in a diagnostic task in a very detailed way. Neither did we analyse the conditions of particular situations and the persons' accounts of them. However, some hypotheses could be derived with regard to the situated construction of diagnostic judgement (Norros 1995). A central question that came up was the role of repeating problems in the development of disturbance orientation, and consequently, the role of repetition in the development of expertise. The above example from our material demonstrated that when a problem in the process occurred repeatedly, the pressure for a situational transformation from a routine disturbance handling to unofficial diagnostic action increased. With the help of the traditional notion of habit we may interpret this observation as an indication of a situation in which the restrictions of the developed routine become overt through the repetition of the problem. The reoccurrence of the problem, that was also identifiable by the analyst, launched a search for a more developed way of tackling it. Such a search for new solutions may be interpreted as a sign of reflection in action (Miettinen 2000).

The use of the overt disturbance as the reference in the analysis may falsely lead to the conclusion that if the situation had not actually and explicitly demanded reconsidering of the routine, that is reflection, the present action of the operator would not have expressed reflectivity, but mere habitual routine. In the previous chapter we argued that habit potentially contains both routine and reflection – as indicated in the conception of reflective habituality. According to this conception reflectiveness of habit is not determined by the situation, e.g. by a disturbance. Rather, it is a result of the actor's personal relationship to the environment. Habit provides continuity in the relationship with the environment, and this continuity needs both repetition of established operations, and reflection of their appropriateness in every particular situation. Thus habit, as a reflective routine orients towards the future (Kilpinen 2000), and provides possibilities for anticipating future events.

The latter line of thought leads us to a conclusion regarding the emerging methodology. It appears that restricting the analysis of action to the responses to actual disturbances may be misleading as it easily results in an unsound contrasting of habit *and* reflection. This may follow because by allowing the analysis to be evoked by the disturbances, the attention in the analysis focuses on the actual situational sequence of operations. Using the externally defined event, here the disturbance, as a reference in the analysis bears an analogy to the role of stimulus in the reaction time experiments (see Chapter 3). As Järvilehto claimed, the stimulus should rather be seen as a result of the developed skills of the subject than as an external cause of his or her behaviour (Järvilehto 1998a).

Consideration of the reasons for action and understanding their meaning would complete the analysis of courses of action by adding the further level of analysis, the analysis of habits. The latter stage of analysis would reveal the potential that an actual action expresses. An analysis of the conduct in maintaining the normal flow of actions, e.g. undisturbed running of the FMS process, without assuming knowledge of the success of the end result, would possibly be more informative for analysis of habits. In these conditions the interpretation of the weak signals of the environment and the anticipatory actions would distinguish between practices. It appears, furthermore, that understanding the adaptive flow of action in such situations would suggest the existence of the form of intentionality that was referred to in the previous chapter as absorbed coping (Dreyfus 2001).

In order to identify a habit it would be necessary to become informed of whether the actor has understood a particular sign as relevant reason for acting (von Wright 1998a) . With this requirement in mind we realise that the issue is not whether to study action in a disturbance situation, or in what could be considered a normal situation. Rather, the methodically decisive demand is to define action from the point of view of the subject through *making his reasons intelligible*, normally through *inquiry* with regard to action.

If behaviour should be analysed from the perspective of the normal flow of action, the problem of defining the situational reference to the analysis emerges. Thus, instead of analysing actions with reference to their externally defined success, we should analyse the characteristics of the situations as constraints to and affordances for the realisation of the intentions of the persons to reach the results. Consequently, development of a *modeling* approach emerges as a task for further investigations.

In the present chapter we restricted ourselves to those theoretical concepts that were used in the referred FMS study. The orientation concept and especially the notion of disturbance orientation represent the first attempt to create the Core-Task Analysis methodology. From the present perspective, it seems that even though we were doing badly we were anyway moving into the right direction (Siikala 1997). In the FMS study orientation was conceived both as a person's stance with relation to the object of activity and also as certain practice in the disturbance situation. The latter, the behavioural expression of the personal sense was later to be called habit of action. Habits of action are definable through observing how persons take into account the situational constraints of action. When the above distinction is made, it appears natural that orientation should be defined by inquiring about the actors' conceptions of the object of activity. Habit of action should be inferred on the basis of observations of behaviour, which is made intelligible through process tracing interviews.

5. Ways of acting in the handling of disturbances in nuclear power plant operations

The empirical studies to be presented in this chapter demonstrate the emergence of the Core-Task Analysis method until to the final step of adopting the pragmatist concept of habit into its theoretical arsenal. All these studies deal with nuclear power production and they are focused on the control room operators' decision making in difficult disturbance situations. The studies were conducted in simulated situations in full scope training simulators. We begin with a study in which a human error approach to disturbance handling was used. Then we shall demonstrate the development of an alternative ecological research approach by describing our work on functional modeling of the domain and analysis of situational constraints of action as the prerequisite for analysis of actions. Thereafter, with the help of two studies in two different nuclear power plants, we describe the emergence of our method for the analysis of complex performance. Finally, we make some methodical conclusions.

The analysis of nuclear power plant operators' work is a challenging task. It is accomplished cooperatively within an international research community, within which the research approaches and methods are also developed. The prevailing methodological orientation in the human factors research in the nuclear domain was and still is the cognitive information processing approach to which we were committed. However, our aim was, to proceed into a new direction. The first steps in this path were already taken in the FMS-study described in the previous chapter.

Work in the nuclear power plant control-room

The societal objective of the nuclear power plant is to produce energy in a sustainable way as efficiently and safely as possible. The exploitation of nuclear fission for the commercial production of energy is a result of intensive scientific and engineering work. The radioactive character of the fuel sets strict safety demands on the operation of nuclear power plants (NPP). Therefore, the complexity of these plants is not only due to the technical demands of power production, but also to the defences that are constructed for ensuring the reliable and safe operation of the process. The requirements for safety have continuously increased as a result of the accumulation of operational experience. A careful definition of the tasks and responsibilities of the personnel and appropriate organisational structures and practices in the power plant are needed for completing the technical defences. The defences also require that the surrounding communities be prepared for emergencies. The responsibility of the nuclear regulatory authority is to proactively ensure the highest possible level of safety in the plants.

The control room operators constitute the operationally central section of the power plant personnel. The operators continuously supervise and control the functioning of the nuclear process and the production of energy to the electricity grid. The normal daily work of the power plant personnel also includes carrying out various periodic tests and other preventive tasks that aim at ensuring the safe operation of the plant. Operators are qualified to act in disturbance situations, in which the technical and other defences have failed and the stability of the process has become threatened.

Optimal action of operators in disturbance situations is an important resort of maintaining the process within safe boundaries. Appropriate interpretation of instructions in disturbance situations is a task that requires skill and judgement on the part of the operators. The entire NPP organisation, including various functions e.g. maintenance, techniques and design, safety issues, personnel resources and management provide support for the work of the operators and for the maintenance of the generic objectives of the plant in all situations.

In the following, we shall analyse operators' practices in disturbance handling, and develop further the idea introduced in the previous chapter that the situational judgements concerning the goal and the conditions of action are regulated by the subjects' conceptions of the object of activity.

5.1 Analysis of decision-making errors as a means of describing disturbance handling

The notion that the occurrence of disturbances is a "normal" state of the system was proposed in the previous chapter. We also claimed that disturbances manifest the limitations of design. These limitations may be compensated and the design completed through adaptive responses and design-like actions of the operators of the system. However, it is a theoretically and practically challenging task to enhance adaptability of the system through promoting design-like actions in operations in safety critical and complex domains. These challenges have been analysed extensively in studies of complex organisations that draw on an approach labelled High Reliability Organisations HRO (Rochlin 1993, Schulman 1993, Weick & Roberts 1993). Notwithstanding the arguments of HRO analyses standardisation and prescriptive implementation of pre-defined operations are dominant measures for maintaining reliable functioning of the system. The advantages of standardisation in the form of better control and predictability are valued higher than the disadvantages resulting from not being able to make use of the adaptive potentials of the human actors.

The prevailing organisation strategy in complex high-reliability domains relies on standardisation of actions. It reflects a particular epistemic attitude that conceives human action in terms of technical rationality descried by e.g. Schön (1988). This very attitude becomes evident also in the methodological choices of the investigators who study human performance in these organisations. The approaches represent predominantly the deterministic paradigm described in Chapter 2 (Eskola 1999). In the NPP human factors studies operators' action is comprehended in prescriptive terms. The notion of human error has provided a central theoretical orientation in these studies (Reason 1990). Human error studies typically aim at enhancing the control of predefined tasks and at prevention of errors that according to statistics appear to be major causes of disturbances, incidents or accidents.

Human error analysis of NPP operators' performance

Human error was also our point of departure when we first started to study NPP operators' performance (Norros & Sammatti 1986). His study was part of a Nordic collaborative nuclear safety programme within which we became acquainted with the work of Jens Rasmussen. Our study took place at a two-unit nuclear power plant and included all the twelve control room crews of the plant. We collaborated with the chief simulator trainer of the plant, who provided the necessary knowledge of the domain and operations. We used two different disturbance scenarios in the experiments, which were organised as part of the crews' regular simulator training.

The aim of the study was to test a tool intended to facilitate analysis of performance in simulator training. This method consisted of two major parts. The first part was modeling of the disturbance as a sequence of tasks. The second part of the method consisted of a description of action by means of identifying possible deviations of the prescribed task as errors and classifying these errors.

Modeling of the disturbance. The two disturbance scenarios that were used in the experiments were carefully described. In terms of the classification of the modeling approaches discussed in the third chapter, our method was normative and instruction-based. The prepared model of the task comprised a sequence of events in the process and the adequate, in some points optional, operational reactions to them. The described sequential models were interpreted as the ideal way of handling the disturbances.

The complexity of the two scenarios used in these experiments was varied. There was no formal measure of complexity but instead we relied on the expert judgement of the chief simulator trainer. It was expected that the complexity would manifest itself in different levels of difficulty in managing the situations. The scenario used in the first experiment was a leak in the live steam manifold. The model of the scenario comprised 114 steps. The scenario was judged as a rather clear cut and transparent disturbance situation, but its challenge was that it evolved rather rapidly, particularly at the beginning of the event. As a whole, this disturbance situation was judged as not very complex and rather easy to manage. It required a rapid diagnosis, on the basis of which suitable operating procedures could be selected.

The disturbance used in the second experiment was partial breaking of plate fixing bolts of the primary manifold of the steam generator. The model of the scenario consisted only 43 steps, but it was a physically complex occurrence and less transparent than the first disturbance. It was assumed that decision making for the correct operative measures was a rather demanding task.

Description of actions. Operators' actions were described by means of an analysis of the deviations from the prescribed ideal task sequence (Hollnagel 1981a, Hollnagel 1981b, Hollnagel 1982, Hollnagel & Rasmussen 1981, Rasmussen et al. 1981). The method provided a two-way classification of the observed deviations or errors. The first dimension was called *decision function.* The functions denoted the main elements of the decision-making process. We made minor terminological changes to the original classification and decomposed the decision process into the following functions: observation, diagnosis, decision, execution and feedback.

The second dimension was called *error cause* and referred to possible causes of the observed deviations. Two sources of error causes were included, i.e. internal error mechanisms and external causes. This classification originated in an earlier work of (see also Rasmussen 1986, Rasmussen et al. 1981). We used a slightly modified version of the original classification. The list of error causes consisted of the following major categories: control room layout, procedures and their use, co-operation among the crew, knowledge and action control, external action disturbance, simulator effect. Altogether 22 items were included under these six categories (Norros & Sammatti 1986).

The intended difference in the level of difficulty of the disturbances became manifest in the total error rates. The average number of errors per crew was 9 in the first transient and 13 in the second.

We expected to observe differences in the error distributions with regard to the two dimensions, decision-making function and error mechanism, as a function of the complexity of the task. We were also interested in the connection between the overall accuracy of performance and the type of errors. In order to clarify the latter question we divided the crews into two groups, low error and high error crews, according to the crews' overall level of errors.

Our results indicated that the crews' levels of achievement were rather stable. Those crews who performed well in the less complex scenario also managed better in the more complex one, and vice versa.

We found further that errors were typically decision or execution errors. No difference in distribution of errors with regard to the decision function was found between the less and the more complex scenarios, nor between the less and the more successful crews. However, we observed differences in the error distributions with regard to the error cause. Hence, it became evident that both high and low error crews had difficulties with regard to process knowledge when the complexity of the scenario increased. The less successful crews had further problems in the evaluation of the applicability of procedures and in cooperation in the more difficult transient.

We also scrutinised the courses of performance of each crew. It was found that in the more transparent but fast scenario, correct identification of the leak correlated with overall success in the task. In the more complex scenario no clear-cut correlation was observed between the correctness of the initial diagnosis and the overall success.

Lessons learned from the human error study

We interpreted that the stable difference between the crews with regard to the accuracy of performance would demonstrate different approaches to act in a disturbance situation. The achieved results were interpreted to indicate that the advantages and weaknesses of the assumed ways of acting became manifest when the task demands increased, i.e. when the identification of the problem became less clear cut, the selection of operations required judgement and the knowledge demands increased. We reasoned further, that under these conditions the differences in the ways of acting became manifest through differences in the ability of the crews to take advantage of the available resources that the procedures and co-operation would have provided.

The method used in this study was based on the idea of a linear information processing that is launched as a response to the stimulus situation. The theoretical problems of this approach were discussed earlier in the second chapter. Our study demonstrated some of the drawbacks of this approach in practice. Hence, it became evident that as the subjective goals and intentions of the actors were not inquired and taken into account in explaining the actions, it was difficult to define the unit of analysis and to distinguish the decision functions. Even though a trainer who had the necessary expertise of the domain classified the errors, it was difficult to accomplish the task. The trainer considered the whole scenario as the unit of analysis. Thus e.g. diagnostic function was equated with identification of the problem as a leak and the specification of its source. Problems that occurred in this complex task were represented as one deviation in the sequence and classified as diagnostic failures. The stabilisation of the process was decomposed in greater detail and comprised many choices and executions of operations. As a consequence, the possible number of errors in diagnosis was bound to be lower than that in the decision and execution of operations.

The trainer found the classification of errors with regard to the error cause to be easier and the results of this classification were also considered more informative. We formulated the interpretations regarding the crews' ways of acting mainly on the basis of the differences found in the error causes. However, we were obliged to conclude that our error-based analysis of actions did not offer sufficient grounds for verifying them. This was due to the fact that error classification did not provide a means for a detailed analysis and description of the construction of disturbance handling actions and how the available resources are utilised in a situation. Nor did it provide an acceptable explanation of the regulation of actions. Therefore our interpretations had to be considered as hypotheses for further studies.

The operators' opinions supported the above methodical conclusions. Three months after the completion of the experiments the operators were queried about the relevance of such studies for their training. The majority of operators did not see error classifications as particularly relevant for training and learning. The rather negative attitudes of the operators may also be interpreted as a reaction against this kind of post–hoc analysis of action (Woods 1994). The operators may also have had other reasons for their disappointment. The results of the experiments were, unfortunately not discussed and evaluated properly with the operators themselves, and no explicit conclusions regarding the practical significance of the results were drawn by the organisation (Norros 1989b).

One may wonder why the investigators failed to provide the feedback and involve the operators in reflection and development of their performance. In retrospect it appears that because the analyst already knows the course of action and its result, he easily oversees the uncertainty in the situation that the operators confront and the constructive nature of the actual action. The concepts used by the investigators in the comprehension of the operators' performance were prescriptive. They were not tuned to comprehending the actions of the operators who were acting on the evolution of the process. This would have been necessary for reflecting and evaluating the possibilities of recovery together with the operators. Hence, the need for development of new units and concepts for the analysis of the constructive disturbance handling became evident.

5.2 Functional modeling of the domain and the situations

In his article concerning the methods of naturalistic decision making research Kenneth Hammond contrasted the methodological choices of Wilhelm Wundt and Egon Brunswik (Hammond 1993). When explaining the Brunswikian way of thinking, Hammond referred to P.E. Meehl's remark that "proper sampling of situations and problems may in fact be more important than proper sampling of subjects, considering the fact that individuals are probably on the whole much more alike than are situations among one another" (Meehl 1990, p. 39). This statement indicates a strong ecological position which Hammond himself followed in developing his "Cognitive continuum theory" (Hamm 1988, Hammond 1980, Hammond et al. 1987). As indicated in the second chapter, Gibson had also symphatised with Brunswiks's probabilistic functionalism because of its ecological approach to human conduct. His concept of affordance expressed the functional connection between the environmental features and the human actions.

As conclusions from our human error studies we found it necessary to develop a way to conceptualise the constraints and possibilities of the domain and the situation as a basis for understanding the construction of the course of action in a situation. We found the theories of Brunswik and Gibson to be fruitful background theories in this attempt that should begin with modeling the domain and situation. Jens Rasmussen's work (Rasmussen 1986) provided a further basis for the development of our modeling approach. Our way of modeling the situations aims at describing the affordances of the domain. These were understood as the outcome-critical features of the environment that express the potential of the environment to become an object of intentional activity. The concept of "object of activity" was borrowed from the cultural-historical theory of activity and the function of the object to motivate the whole activity system was acknowledged. Our modeling method first conceptualised the affordances of the domain in generic functional terms, and then proceeded into a description of the possibilities and constraints for action in a particular situation.

Modeling of the domain

Besides the theoretical influence of Rasmussen, the modeling work was shaped by experience from a study concerning the design of a disturbance handling system for nuclear power plants. The system was validated empirically in simulator studies (Hollnagel et al. 1983, Kautto 1982, Kautto 1984). The functional modeling approach developed in this context was later used by us in a further study that focused on the development operation-oriented design criteria for the display of process information. The attempt in this project was to derive an information presentation concept that would, under strict limitations of space (presentation only 2–5% of the total process information), promote the operators' understanding of the process phenomena and facilitate control operations. It should also improve the operators' conceptual mastery of the process. The conceptual basis of the modeling framework is presented in Table 5 (Norros et al. 1986).

Table 5. The conceptual basis of modeling of the NPP domain for the structuring of information presentation (with minor adaptations Norros et al. 1986).

Modeling of the process / Mastery of the process	Explanatory depth of knowledge	Type of modeling	Levels of presentation of information
Comprehending the system ↕ Readiness to operate the system	*Genetic* explanation = energy refinement and mE-balances	***Functional***: - Functionally organised presentation of processing stages and functions, sub-functions and variables - Supporting design basis	I Objectives Critical Safety Critical Availability Critical Efficiency
	Causal explanation = physical phenomena and laws	***Locational/systemic:*** - Operational overview with main systems (PI-displays) - Systemic organisation of sub-systems and main components, and group control sequences	II Systems
	Descriptive explanation = flow diagrams (pipe lines) and Instrumentation systems =>technical model	***Locational/classificatory***: Operational control with components and variables - Classificatory organisation of operative procedures with corresponding components - Supporting design basis: - plant protection - automatic control sequences - feedback controls - interlocks (etc.)	III Subsystems and components

Process information is one of the major resources in the control of the process. Our starting point was that the information presentation should be such that it facilitates the operators' comprehension of the system and promotes their ability to control the process (first column in Table 5). The three other columns in Table 5 denoted different aspects of modeling that we considered when constructing the conceptual basis for the information presentation system. The first aspect of modeling referred to the explanatory depth of knowledge of the process. We distinguished the *genetic* or developmental explanation that captures the generic dynamic principles of the system, the *causal* explanation that identifies cause-effect relationships within the system, and the *descriptive* explanation that defines and classifies features of the system.

The second aspect in our framework referred to the type of modeling that may be used to structure knowledge of the process. We distinguished *functional* and *locational* concepts, and the latter was divided into systemic and classificatory concepts (second column in Table 5). The distinction between functions and location in the process was considered to be decisive from the point of view of controlling the process. Thus, the functions should be decomposed into main functions (m&E balance and the heat transfer), functions, sub-functions, and variables. Correspondingly, the location in the process should be decomposed into systems, subsystems, auxiliary systems, sub-auxiliary systems, and components. These were to be mapped with the main functions.

The levels of presentation of information were designed to correspond with the purposes that the information system should facilitate. The main objectives of the process were seen to be to maximise power production, under the condition of successful balancing between the different sub-goals of safety, availability, efficiency, maintainability and quality of the process and the product. The functions of the system were defined separately for each goal. For example, in a pressurised water reactor (PWR) the main function of mass and energy balances and heat transfer may, from the safety point of view, be decomposed into eight essential functions, the critical safety functions (Corcoran et al. 1981, Kautto 1984). The functions are presented in Table 6, in which they are connected to systems (locations) of the process.

Table 6. The critical safety functions and the corresponding systems (Kautto 1984, Nelson 1983).

Critical Safety Functions	***Location in the process***
Reactivity	Core
Core heat removal Coolant inventory Pressure control	Primary circuit
Heat transfer from the primary to the secondary circuit	Secondary circuit
Containment temperature /pressure control Containment integrity	Containment
Power for emergency subsystems	Electrical systems

Our modeling framework had connections with the abstraction hierarchy model proposed by Jens Rasmussen. His method comprised two dimensions, the part-whole and means-ends dimensions that are seen to constitute a matrix with the help of which particular operating sequences may be comprehended (Rasmussen 1986). Our approach aimed to provide a conceptual framework for the design of process control and information systems of complex plants (Kautto 1984). However, we did not develop it further to form a basis for a design methodology as e.g. Kim Vicente (1999) or Morten Lind (1994) have done. In his recent papers Lind has pointed out problems in Rasmussen's abstraction hierarchy and identified needs to analyse its applicability in the design of artefacts (Lind 1999 and 2003). He also argued that his multilevel flow modeling should not be considered as an integrated part of the Rasmussenian abstraction hierarchy approach.

Use of domain models in training

The abstraction hierarchy model of Rasmussen and also our conceptual frame shared the ecological idea that modeling of the physical domain should be connected with intentions to control it. This operation-orientedness was also thought to legitimize the use of such modeling approach in the training of operators. It was assumed that the models would promote the building of an explicit orientation basis for operations. This should, furthermore, facilitate the operators' conceptual mastery of the process and guide actions (Galperin 1979). Development of the orientation basis would improve the structuring of the large amount of formal knowledge to be acquired by the operators and facilitate the linking of formal knowledge with operating experience.

The framework was utilised as part of a developmental study that aimed at a new type of operator training (Engeström 1987, Norros & Kautto 1984, Norros et al. 1986). We examined the possibilities to develop model-based training to complement other forms of NPP operator training. We applied newly established developmental training concepts (Engeström & Engeström 1986, Toikka et al. 1985).

Our model-based training programme was carried out in one power plant with one operating crew and it consisted of seven sessions with duration of 32 hours. The structure and content of the training is presented in Table 7.

Table 7. The content of an experimental model-based training programme for nuclear power plant operators (Norros & Kautto 1984).

Content of the experimental training based on modeling of work (32 h)

1. Introduction to the experimental training (1h)
   - basic goal and idea of the training programme
   - content of the sessions
2. NPP process control as an activity (3h)
   - modeling of the activity with the help of the activity system model
   - identification of contradictions and constraints within the system
3. Object, Tools, Process (6h)
   - lectures by a nuclear expert
   - modeling of the basic content of the elements (object, tools, process)
4. Process control as a developing work (4h)
   - analysis of the history of power production
   - modeling of the present developmental challenges
5. Action in a disturbance situation (6h)
   - critical evaluation of the crew's own performance in a simulated difficult disturbance situation in the full-scale training simulator; video-recordings and logouts from the training session were used as material
6. Development of information presentation (6h)
   - cooperative production of criteria for a new information presentation system from the point of view of operations; the modeling framework was used and a proposal for information presentation was prepared for discussion
   -paper and pencil simulation of a disturbance with the aid of the developed information
7. Development of work (6h)
   - collective conceptualisation of the central developmental demands of work

The modeling of the physical NPP system was embedded in the training program. We utilised the *activity system* approach to structure the training programme (Engeström 1987). The concept of activity system (the triangle-model explained in Chapter 3) was first introduced to the operators and then it was used by the operators as a tool in the production of further models regarding their own work. The subject, tools and the object interact in a complex and dynamic way in the production of the result, the maximum amount of energy under the constraints of balancing safety, availability, efficiency, maintainability and quality.

The physical phenomena of the NPP process and the systems involved were depicted in a basic *process model* (Figure 10). Each physical phase of the process was discussed thoroughly in the third session in the program.

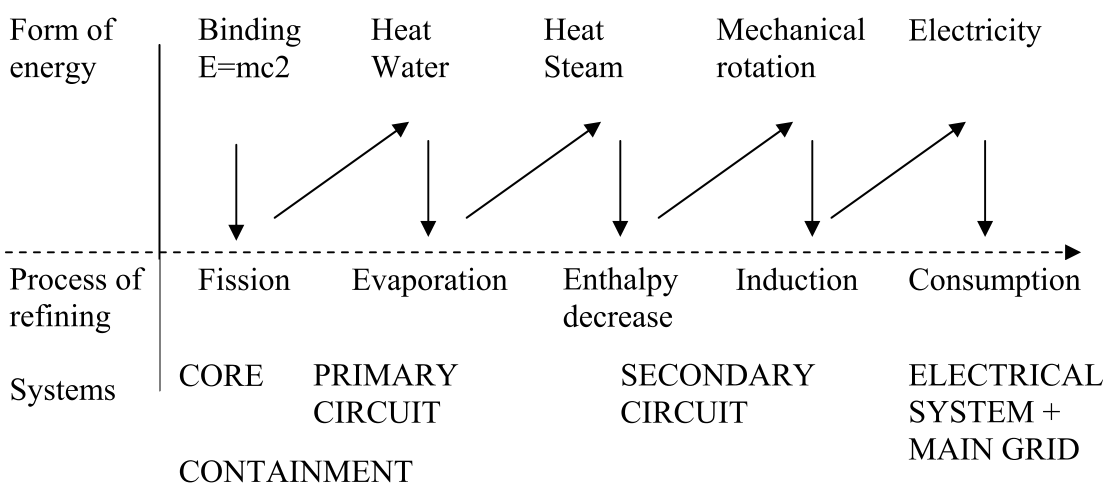

Figure 10. Process model of NPP production. The fundamental physical phenomena and the main systems for their technical realisation (Kautto 1984, Norros & Kautto 1984).

The fourth session was designed to create a *historical perspective* to power production. In this task we utilised the activity system model, with the help of which the tensions within the system were analysed and the transitions to new forms of production were comprehended. The aim was to make the particular features of the present form of production understandable and the constraints on action explicit. In the fifth session we focused on the analysis of NPP operations as situated action. This was accomplished by an analysis of the crew's performance that was videotaped. We drew the operators' attention especially to ways of using process information. In the next session the insights gained were utilised for deriving demands on information presentation. The last session was devoted to conclusions regarding developmental needs of the work. The results of the experimental training were later utilised in the construction of the information presentation framework (Kautto 1984).

From the very beginning we had in mind that modeling of the domain may serve both the design of artefacts and the improvement of operators' performance. Furthermore, it became clear that both the design and training aims are reached better if modeling is organised as a cooperative shared action among the designers, researchers, domain experts and the operators themselves. Evidence of the efficiency of such modeling activity was later provided by Leppänen and her colleagues, who developed a participatory modeling framework technique to meet the training and technical development needs of the Finnish pulp and paper industry (Leppänen 2001).

We considered, moreover, that a generic conceptual modeling is not sufficient for design or for training. Descriptions of the environmental affordances in particular situations would be needed for the understanding of the use and the usability of artefacts. Moreover, it was understood that the definition of the action relevant features of the domain might require analyses of the actual performance of the operators. The constraints and possibilities become overt through their becoming accounted by the operators. Therefore, an analysis of how the available resources are exploited in practice becomes necessary. Our further conclusion was that in order to accomplish such analyses, we must develop *situational models of the domain*. These would serve as a reference against which the analysis and evaluation of actions could be realised.

Modeling of situations

We began to develop a way to describe situational features of the environment. These features were interpreted as *affordances* and as such they had to be described from the point of view of human action and decision making. The method for modeling of situations was created in four successive studies, in which altogether eight different severe disturbances of the nuclear power process were described. The developed modeling method may be labelled as *a functional constraint-oriented analysis of situations*.[5] Several colleagues contributed in the development of the approach, especially Ari Kautto, Jan-Erik Holmberg, Kristiina Hukki, Markku Malinen, and Pekka Pyy. Different perspectives to the modeling were represented in this joint work, i.e. nuclear physics, human factors, NPP operations and reliability analysis. We shall describe the development of the modeling method and demonstrate it with examples of its most recent use.

The first version of the functional constraint-oriented analysis of situations was created in a study that focused on diagnostic judgement of NPP operators. Judgement was studied in a simulated severe disturbance situation (Hukki & Norros 1993). In this study we made use of the material from the above mentioned validation study that concerned a new operator aid to be used in disturbance situations (Hollnagel et al. 1983, Kautto 1984). We were interested in tracing the actual course of actions and therefore needed a reference with the aid of which we could observe and interpret the operations of the crews. As indicated above we had already developed an approach for the analysis of the generic functional demands of the domain. This served as a basis for the modeling of the experimental disturbance scenarios in the studied situation.

[5] More recently we have used the notion functional situation models when referring to the results of modeling situations Norros L., Savioja P. 2004. Modelling of the activity system – development of an evaluation method for integrated system validation. Presented at Enlarged Halden Programme Group Meeting, Sandefjord, C2.9.1–12.

A scenario to describe a loss of coolant accident (LOCA) was prepared for the experiments by Kautto (1984). The complexity of the scenario was increased by adding several minor disturbances to the main event. Kautto proposed different types of conceptualisations to be used to describe the disturbance. First, these included a description of the major malfunctions. In the second phase the malfunctions were analysed and presented from the point of view of their functional consequences, i.e. which critical safety functions were concerned, and how severely the event challenged them. The most essential control operations that maintenance of the critical functions would demand were also analysed and presented in the model. In the third phase, a timeline model of the process events and operations was constructed, which also indicated the consequences of different operations for the process.

The task was thereafter conceptualised from the psychological point of view. The task could be seen to consist of intertwined diagnostic and operating demands. Conducting corresponding actions was seen to require an interpretation of the meaning of the whole situation. This interpretation was constructed on the basis of actually making use of the available resources, i.e. process information and the operating instructions (see next section).

In order to analyse the construction of an interpretation of the disturbance situation we thus needed a description of the *available process information*. The information should also be analysed according to its possible relevance for diagnostic and operative purposes.

The modeling of the available process information in the particular disturbance situation was based on a careful analysis of the courses of action of six crews. The above mentioned description of the disturbance was used as the inferential reference and further background knowledge was provided by domain experts. As a result we created a classification of available process information in this particular situation (Hukki & Norros 1993). Unfortunately, our material did not offer practical possibilities to tackle the operators' usage of procedures. Therefore we did not analyse the information content of the procedures in detail.

The further modeling of the situation from the point of view of psychological demands took place in two phases. First we classified the diagnostic hypotheses regarding the localisation of the leak:

Leak in primary circuit
- outside containment or
- inside containment

Leak in secondary circuit
- outside containment or
- inside containment.

In the second phase, the process information that was available for inferring the possible hypotheses concerning the location of the leak was analysed according to the diagnostic informativeness of this information (Hukki & Norros 1993, p. 1223). In defining the informativeness we differentiated between function and location, which was earlier found to be a control-relevant distinction (Kautto 1984). Consequently, process information was defined *functionally informative if it could be used as evidence of the functional state of the process on a global level*. Such information enabled inferences regarding the functional state of the whole process (e.g. boiling margin indicated heat transfer through the system) or a functionally essential part of it (e.g. primary pressure indicated the global physical state of the primary circuit). Process information was seen to be *locationally informative if it could be used as evidence for the location of the source of the disturbance* (e.g. the normality of the parameters in the pressuriser bubbler indicated that the safety valve was closed. Hence the valve could not have been the source of the leak). This classification was then utilised as reference in the analysis of the crews' inferences regarding the localisation of the leak.

Further development of modeling of situations

The functional constraint-oriented analysis of situations was developed further in several successive studies (Holmberg et al. 1999, Hukki 1998, Hukki & Norros 1994, Hukki & Norros 1997, Hukki & Norros 1998, Norros & Hukki 1997). In the following we shall demonstrate the method by models that were created for our most recent study on operating nuclear power plant processes (Norros & Nuutinen 1999, Norros & Nuutinen 2004). This study was another extensive simulator study. It aimed at validating a safety information and alarm system that had already been implemented in the plant. The plant was a boiling water reactor (BWR). The utility was interested in testing the functional features of the system and was prepared to develop operator training on the basis of the study. The information and alarm system was designed to support decision making and action in complex disturbance and emergency situations, in which the critical safety functions may become threatened. The system was tested by six control room crews (with four operators in each crew) from the power plant in a full-scope training simulator in four different serious disturbance situations.

The disturbance situations were selected in cooperation with the experts of the plant and the simulator trainer who participated in the validation tests. The research group was responsible for carrying out the tests. One of the most important tasks in preparing the validation tests was to produce models of the disturbance situations. These models were then used as reference in observing and analysis of the performance of the crews. Complete logouts from the simulator and videotapes of the crews' performance and of the subsequent debriefing sessions were collected. A final group interview with each crew was also carried out. The models and the results of the tests have been presented in a confidential report by Holmberg et al. (1997). The results of the study are reported in detail elsewhere (Norros & Nuutinen 2004).

The models of the disturbance situations comprised two levels. The first level was a *functional decision-making model.* The second level included the *analysis of critical information* and *evaluation of the usability of operating methods*. One of the four disturbance scenarios is used here as an example of the modeling technique. This particular disturbance started with a pressure transient and a regulator problem in the reactor tank. The first event was followed by a leak in the main circulation loop.

A functional decision-making model of the disturbance situation was prepared on the basis of an analysis of the behaviour of the critical safety functions of the process in a situation in which a leak occurred in the main circulation loop. In such a situation the central decision-making and control demand on the operators is the maintenance of critical functions. Hence, on the basis of a comprehensive diagnostic and operative interpretation of the situation, a possibly rapid stabilisation of the process should follow. The operators are expected to take control actions, which should bring the process into an aimed operating state, which may be either production, partial shut-down, or cold shut-down (Hukki & Norros 1998). These psychological demands were utilised when conceptualising the functional decision-making model for the particular disturbance situation, the leak in the main circulation loop. Figures 11a and 11b depict the functional decision-making model for this disturbance. Due to the nature of the particular disturbance the model had two parts.

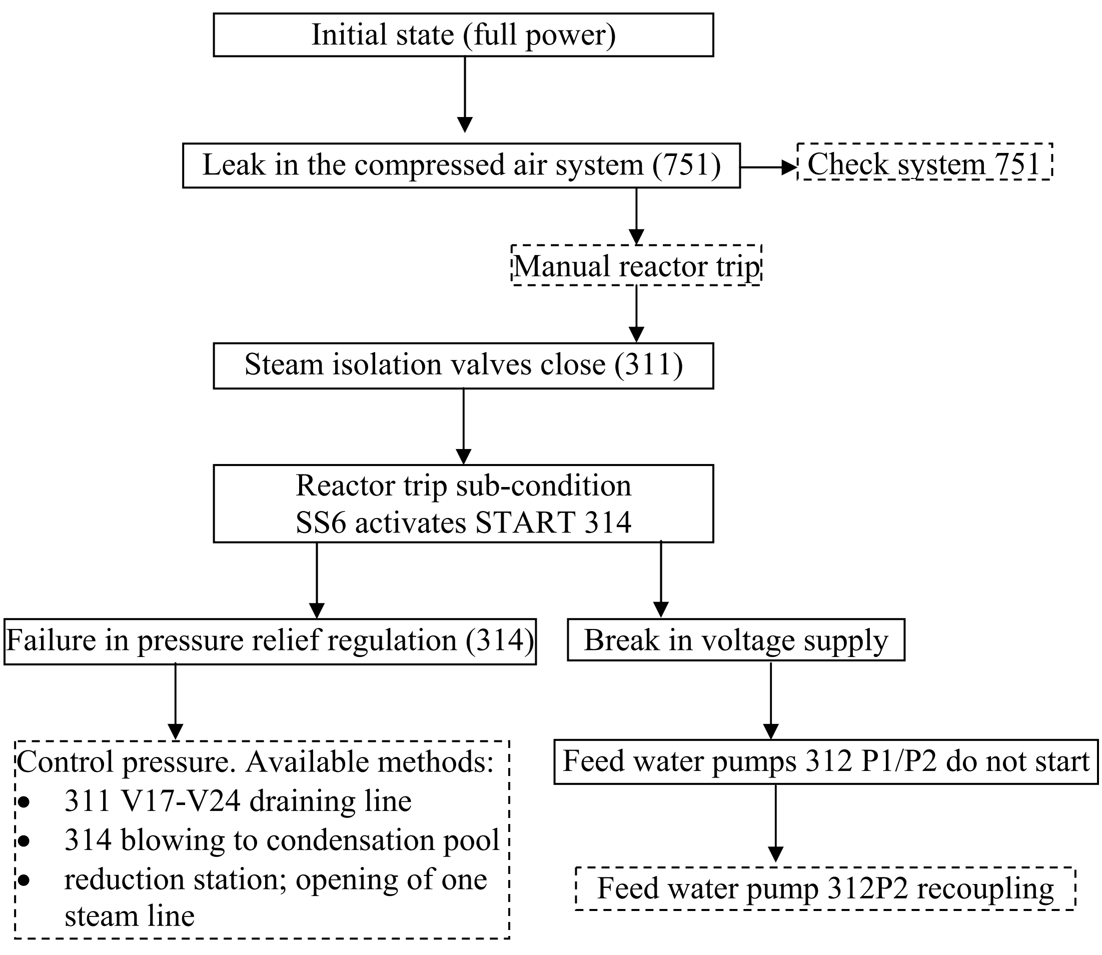

Figure 11a. Disturbance scenario A, phase I: A pressure transient with a regulator problem in the reactor tank.

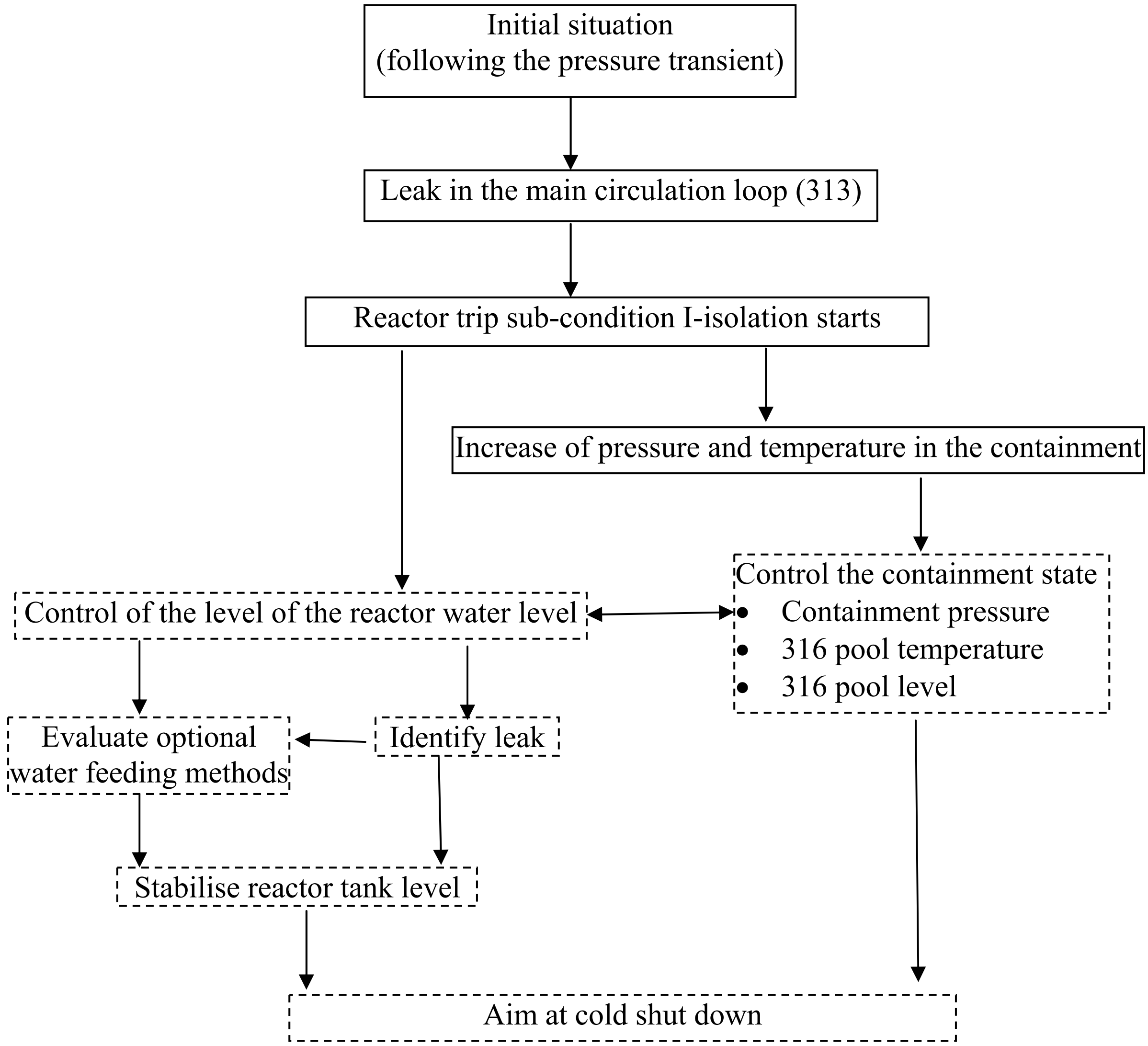

Figure 11b. Disturbance scenario A, phase II: Leak in the main circulation loop.

In Figure 11a and 11b the boxes with solid lines refer to process events or their determinate consequences. Dashed lines indicate possible actions of the operators. The figure conceptualises the whole disturbance situation on a global functional level. Hence, the two main functional demands that the process puts on the operators in the first phase of the disturbance were the demand to control the pressure (left-hand side of the Figure 11a) and to re-couple the feed water pump after a disturbance in the electricity supply. The situation was considered stabilised when the pressure was below 70 bars. At this point, a second malfunction occurred. This was a leak in the main circulation loop. In this phase the demand on the operators was to control the water in the reactor tank (left-hand side of Figure 11b) and to control the state of the containment (RI) (right-hand side of Figure 11b). An appropriate goal for disturbance handling was considered as cold shut down.

The models concerning the critical information and the usability of operating methods in the situation constituted the second level of modeling. At this level each of the main control demands identified in the global model were analysed further. The information that was necessary and available for making diagnostic and operative inferences was described first. The emerging models took the form of tables, in which the critical information was presented and linked to its source in the control room and to its diagnostic and operative meaning. Table 8 demonstrates a critical information table that was constructed for our example disturbance.

Table 8. Critical information table to act as reference for the analysis of the control of reactor tank level (Disturbance scenario A, phase I).

Critical information	**Information source**	**Diagnostic meaning**	**Operational meaning**
Pressure in the reactor tank Measurements: 211K119 211K120	Safety&Alarm System Control console PA106 Reactor trip sub-condition signal SS6 appears two times	Pressure is increasing Pressure > 74 bar	Control pressure Anticipate protection signal SS6 Accomplish initial checks Check pressure Check pressure relief 314 functions Apply safety procedures
314 pressure relief functions	Control console PA07/08 Valves V51 & V48 closed Safety&Alarm System BD	Pressure regulation is not functioning	Apply Safety procedure 6 Methods for decreasing pressure a) draining line 311V17-V24 b) 314V14-V20 c) 311 steam line

Table 9 provides an example of models that were created to describe the available operating methods to decrease pressure in the reactor tank. Each operating method was analysed with regard to four criteria, namely safety, economy, technical feasibility and operating culture. Table 9 demonstrates evaluations that we made regarding the possible methods to decrease pressure after the problem of pressure control had occurred.

Table 9. Appropriateness of available methods for decreasing pressure of the condensation pool 316.

Method	**Evaluation criteria**			
	Safety	Economy	Technical feasibility	Operating culture
311V17-V24 draining lines	Pool 316 temperature and level increase		Small capacity, temporary solution	Number 1 method according to safety procedure
314V14-V20	Pool 316 temperature and level increase		Demands continuous operational control	Number 2 method according to safety procedure
311 steam pipeline which stays prepared for control of residual heat removal	Integrity of containment is not maintained Earlier (phase 1) problem in the control of 311 control valves (air pressure leakage 751)		Demands several operations A proper method with regard to cold shut down?	?

Corresponding tables were also prepared for the second phase of the transient during which the leak in the main circulation loop occurred. A total of five different tables were constructed. Four of these tables were linked with the demand to control the level of the reactor tank after the leak. In the first table the critical information for the identification of the reactor tank level was depicted. In the second an analysis of critical information with regard to the identification of the leak was presented. The third table provided an analysis of the characteristics of the operating methods for maintaining feed water supply. Finally, the fourth table was needed for the analysis of the critical information related to the control of the status of the containment.

Concluding remarks

The decisive feature of our functional constraint-oriented modeling approach is that we do not attempt to describe what exactly the operators should do. Therefore we do not provide a sequence of ideal operations. Instead, our models describe what possibilities there exist for action when certain events take place and, hence, the stability of the system is threatened. The models represent the type of models that Vicente called formative (Vicente 1999). In accordance with Vicente’s approach we describe particular situations from the point of view of generic intrinsic constraints of the domain. These connect to the maintenance of result-critical functions of the nuclear power plant. The operators must take these constraints into account in action in one way or another. Courses of action emerge as a consequence of interacting with the process.

We use the modeling method in order to understand the conduct of the actors, and through this we gain knowledge of the affordances of the domain. The modeling method has been exploited for constructing scenarios for testing and training in simulators, for analysis of normal working actions and also in the post hoc reconstruction of situations in incident and accident analyses.

A fourth area of application of formative modeling is to model for design purposes. Our studies that were accomplished for validating new information systems were examples of modeling for design. The so-called task-artefact cycle has been identified as a generic problem in modeling tasks for design purposes (Carroll et al. 1991). This problem deals with the dilemma that the task analysed with the aim of specifying requirements for a new artefact, changes when this artefact is implemented in use. Therefore, the design of a particular artefact is always outdated. This problem is related to the use of descriptive methods in task analyses. The use of formative methods should help in overcoming the difficulty because the task demands are in that case analysed in a device-independent way (Vicente 1999).

It is usual today that designers attempt to create “instances of real activity” in one way or other (Kuutti 2001). These attempts become explicit in the user studies. However, efficient user studies require, first, that formative modeling techniques are used and, secondly, that that modeling is considered as collaborative activity between designers and the users. The users inform design primarily through acting in normal daily work and only secondarily through their opinions in design sessions. Therefore, comprehensive and frequent analyses of user actions should become normal practice in the design of complex tools. Moreover, the differences in the orientations of the users towards their work should be taken into account because orientations were shown to have an effect on the quality of the users’ expertise. Consequently, the effects of orientations on the users’ input on design should be considered, as well as the implications of these differences for design targets (Norros 2003).

5.3 Orientation-based analysis of diagnostic action

In this section we shall focus on the analysis of situated diagnostic actions. We are interested in finding out how the operators of complex processes make use of available situational resources when making judgements on problematic situations. The modeling of the domain and the situations provided the necessary basis for these analyses.

Analysis of the use the diagnostic informativeness of process information – The PWR study

Above we have characterised disturbance situations that the nuclear power plant control room operators may face in their work. In such situations the operators are required to make appropriate diagnostic judgements of the situation in order to stabilise the system to a safe state. We defined diagnostic judgement as the combination of diagnostic and operative actions that demand from the operators an interpretation of the state of the process. Included in the judgement the operators define what is the operating state to which the process can be re-stabilised (Hukki &

Norros 1993, Norros & Sammatti 1986). In the previous section we also described how we have modeled the constraints of the disturbance situation. In this section we shall explain how such models are utilised in the analysis diagnostic judgement. We shall describe our study that was accomplished in a pressurised water reactor (PWR) type nuclear power plant (Hukki & Norros 1993).

Our study was carried out on nuclear power plant that represented the pressurised water reactor type (PWR). In this study the control room operators' diagnostic actions in a disturbance situation were conceptualised with the aid of a model presented in Figure 12. The model depicts judgement as an intertwined process of diagnostic and operating actions that produces an interpretation of the meaning of the whole situation from both a diagnostic (what is going on) and a prognostic viewpoint (what is going to happen). The interpretation manifests itself in the interactions with the environment, i.e. in the utilisation of situationally available resources that were in this case process information and operating instructions (in more general terms operational methods).

The interactions with the process were thought to reflect underlying differences in the way of *orienting to the situation*. We assumed two generic features, *reflectivity* and *functionality* to characterise the orientations. The two orientational tendencies were thought to contribute to the interpretation of the meaning of the situation (Hukki & Norros 1993, p. 1318). In our conception reflectivity of orientation referred to the actor's own intellectual control over the situation. Functionality of orientation denoted the way of connecting the particular phenomena to the process situation using holistic terms (e.g. critical safety functions).

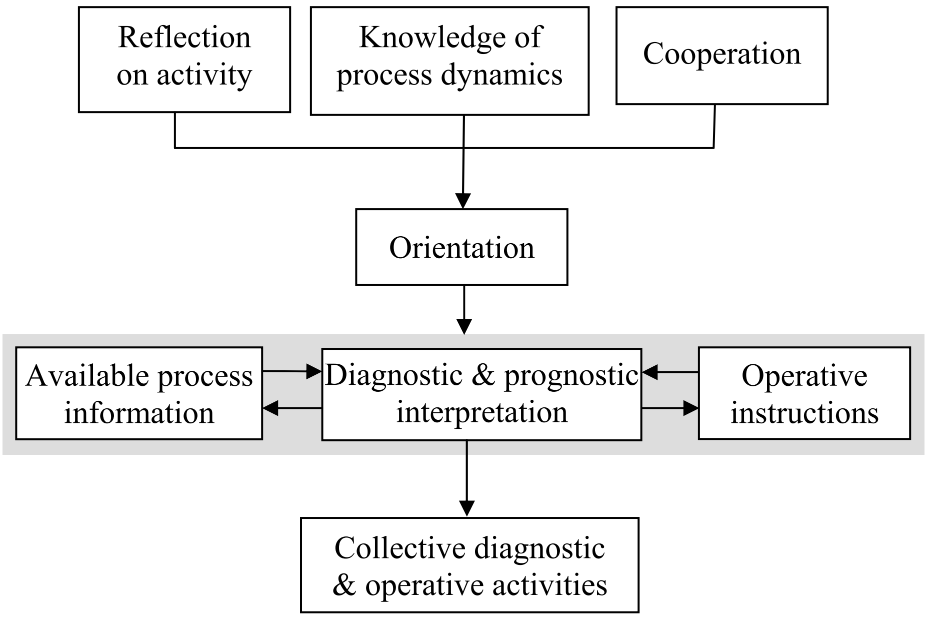

Figure 12. Model of the interpretation of the disturbance situation (Hukki & Norros 1993).

The empirical material of this study was part of the data collected during the validation of critical safety monitoring system (Hollnagel et al. 1983, Kautto 1984). In the analysis of the material we concentrated on the operators' utilisation of the process information. In order to accomplish such analysis we classified the process information with regard to its relevance for diagnosing the nature of the problem and for localisation of the leak. Two types of *diagnostic informativeness of process information* were distinguished, functional and locative informativeness. This classification was utilised as reference in the analysis of the crews' actions and in the interpretation of the observed differences in the efficiency of localising the leak.

The crews' diagnostic actions are presented in Figure 13. It demonstrates the actual hypotheses of the six crews and the time of their occurrence. Each crew is indicated by a capital letters and the figure depicts the crews' hypotheses regarding the location of the leak. It is apparent that localisation of the leak was clearly more difficult for two crews (H and I) than for the other crews (G, J, K and L). The overall efficiency of the crews' performance in stabilising the process was judged as equally satisfactory.

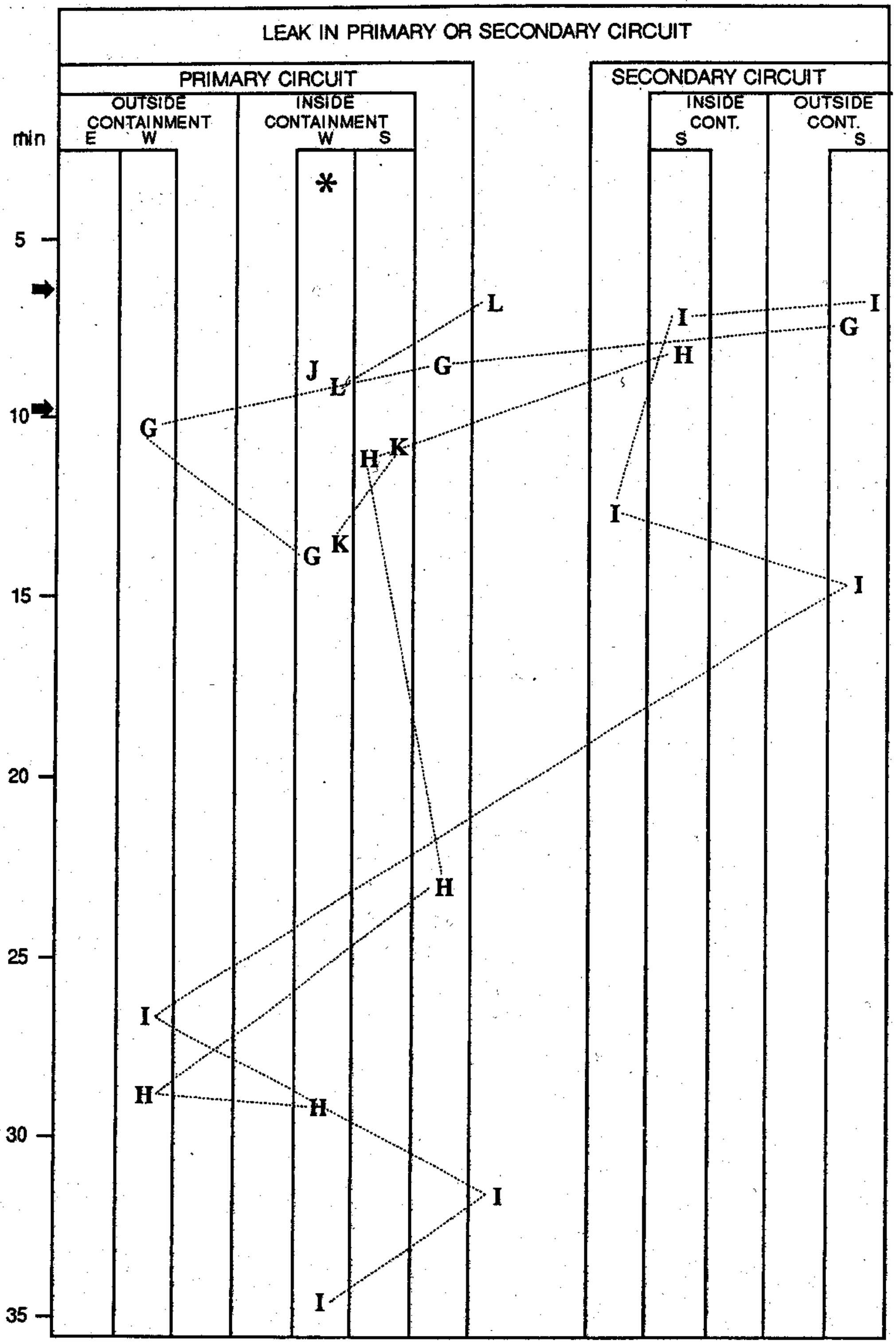

*Figure 13. The crews' (indicated with capital letters) successive diagnostic hypotheses in the localisation of the leak. * = the actual location of the leak; two small arrows =time span within which all symptoms of the leak had appeared. Type of leak: E= energy, W= water, S = steam (Hukki & Norros 1993, p. 1322).*

A careful analysis of the crews' utilisation of information yielded three main conclusions (Hukki & Norros 1993, p. 1321):

The crews H and I made use of the available relevant process information mainly as bases for prognostic inferences. However, they appeared to neglect the possibility of using the information for diagnostic inference. Such an incoherent use of information was not characteristic to the other crews' performance. Instead these crews also utilised the information for diagnostic purposes.

Second, there were considerable differences in the way of making use of the afforded informativeness of process information in the localisation of the leak. The crews H and I used only locationally informative information, whereas the other crews were also able to utilise the functional informative information. When the use of information with regard to the estimation of the size of the leak was considered, again crews H and I, but also crew L, were found to use functionally informative information less adequately than the rest of the crews.

Finally, it could be stated that the crews H and I experienced difficulties in using available process information as counter evidence (which may be utilised as an indication of deficient reflectivity) for their first incorrect hypothesis, to which they seemed to be committed even though they also formulated further hypotheses.

On the basis of the above observations we evaluated the characteristics of the crews' diagnostic judgements in the situation. We could state that one group of crews (G, J, K) utilised functionally informative information both diagnostically and prognostically, and in diagnosis both for localisation and estimation of the size of the leak. The extent of disturbance of the process was comprehended in a coherent way, which became manifest in the adequacy of both diagnostic and operative actions. One crew (L) made use of functionally informative information but the interpretation was less coherent. The third group of crews (H and I) used the functionally informative information only in prognostic inferences but neglected its diagnostic use. In their diagnosis they only used locational information. Their interpretation of the situation was evaluated as incoherent, which expressed itself in a discrepancy between operating and diagnostic actions.

Our interpretation of these results was that the first group could be concluded to have a strong functional orientation. The functionality in orientation was intermediate in the second group, whereas it was clearly weaker in the third group. The reflectivity of orientation was analysed less comprehensively. Signs of deficient reflectivity were be identified in the last group of crews, whose difficulties in comprehending the situation were also manifested in reactions that could be interpreted as signs of subjective uncertainty and emotionality.

The results indicated that, according to our model in Figure 12, the operators adopted different orientations towards the situation, which regulated the use of information in interacting with the object of action. Functionality of orientation referred to such a stance that considered the process as an integral whole, the control of which required comprehension of the particular phenomena in functional and holistic terms. Without such characteristics the framing of the situation was more mechanistic and was accomplished by using structural terms.

The observed types of differences in the operators' orientations may be responsible for the differences in the accuracy of these crews' performance in our earlier human error study reviewed in the beginning of this chapter (Norros & Sammatti 1986). A functional orientation to the process would offer a generic basis for action in all situations, and the strength of this orientation becomes overt in more complex situations. Such an orientation facilitates situational evaluation of the usability of available resources. Without a functional perspective to the basic physical phenomena of the process an optional mechanistic-structural orientation appears useful. It promotes the classification of situations and mapping them to pre-planned actions. Such an orientation does not facilitate reflection on the validity of available resources in the particular situation.

In this study we analysed orientation in a diagnostic task by observing the behaviour of operators, in particular their utilisation of information resources in specific situations. The investigators inferred the relevance of these resources for the attainment of the goal of the task on the basis of the models prepared of the disturbance situation. Unfortunately, we did not have a possibility either to ask the operators about the reasons for their action in the particular situation or to investigate the operators' conceptions of the object of activity. Notwithstanding these methodical deficiencies, we took a step towards a more actor-oriented analysis of behaviour. This was manifested through the use of the concept of orientation. We also approached the concept of way of acting, but this was not used explicitly until our next study.

Analysis of way of acting as the use of situationally available resources: The BWR study

A further study on diagnostic judgement in disturbance situations was conducted at another nuclear power plant that represented the boiling water reactor type (BWR). The study aimed at developing simulator training by providing ways of defining criteria for appropriate action in the control of difficult disturbances.

In the studies of situated action different kinds of process tracing methods are typically used to describe the actual course of actions (Hoffman & Woods 2000, Woods 1993). In these ecologically oriented studies the *courses of action* are seen to be shaped by the particular features of the performance situation. However, as the pragmatists have shown, people do, through their experience, develop generalised means, habits, to cope with the variability of environments. This expresses the generic *potential* for acting. This potential brings continuity into the interaction with the environment. According to the pragmatists, habits will be *actualised* in particular situations in specific *course of actions* (as energetic interpretants of habit). Characteristic of the pragmatist notion of habit is that habits are seen to exist independently of becoming realised in action. We used the notion of way of acting in the NPP studies. The meaning of way of acting was very close to that of the *habit of action* concept that we later derived from the pragmatist notion of *habit.* Way of acting was understood as an operational expression of the person's epistemic stance or attitude to the object of activity, *orientation*.

The idea of distinguishing the *potential* way of acting from its specific *actual* realisation in action emerged from the need to explain the dynamics of the construction of the course of action. In order to do this we found it necessary to analyse particular situations and the actors' personal accounts of them. The emerging method should, through a careful analysis of particular situations, provide us with generic features of action and criteria for the appropriateness of actions. These could be used as a basis for explaining the courses of action. It was obvious that such a method would be useful for predicting action in future situations and therefore valuable for instruction and learning. This was the reason for the NPP to cooperate with us and to conduct this very extensive study. The method that was developed for the plant for evaluating actions for training purposes was named the Tapa-method (Tapa is the Finnish word for habit).

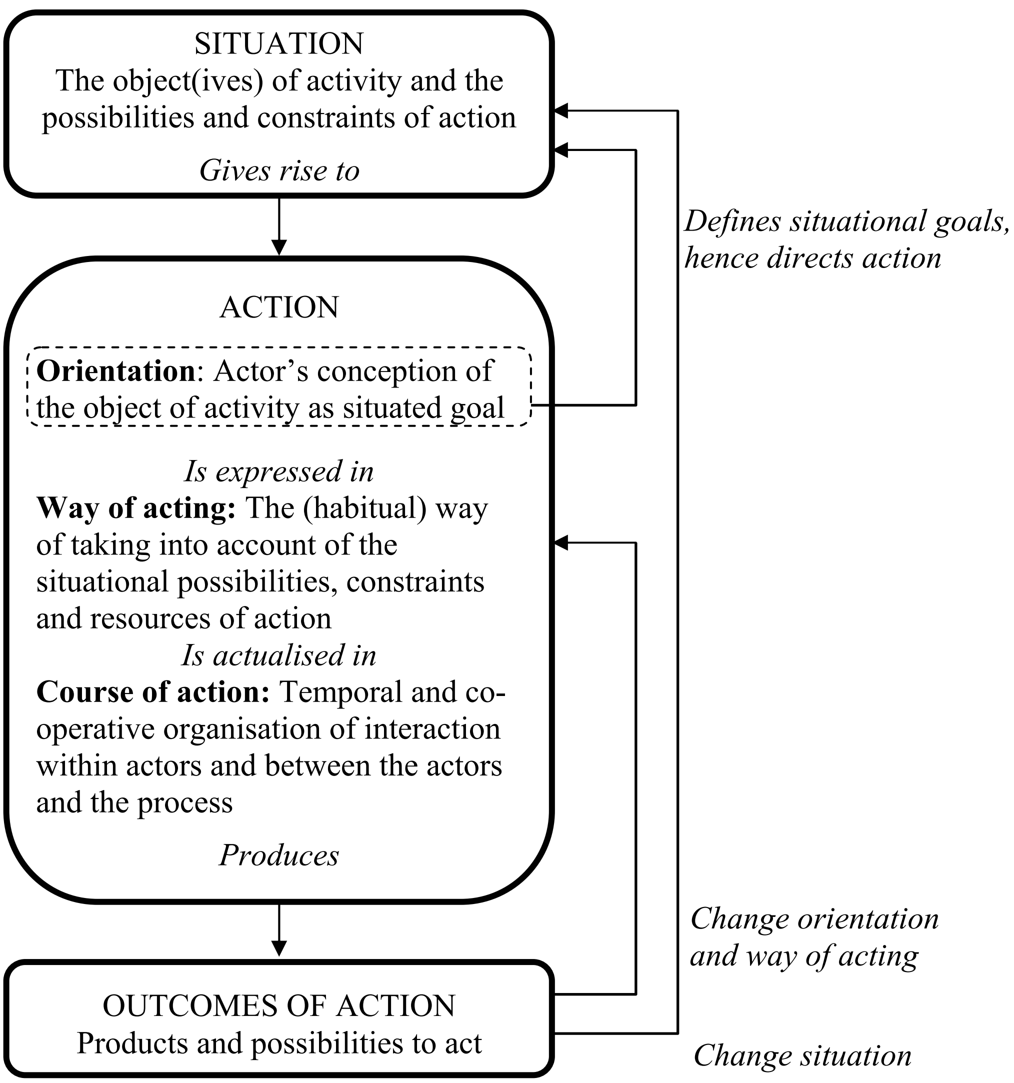

Figure 14. The model of the dynamic construction of situated action (adapted from Holmberg et al. 1999).

The model depicted in Figure 14 illustrates the relationships between the categories that were found relevant for explaining the dynamic construction of situated actions. The model is a modified version of that presented in a joint paper (Holmberg et al. 1999). In the empirical analysis both the conceptions of orientation and way of acting refer to the potential aspect of action. Orientation was seen to direct action through providing a frame for taking the situational constraints into account. Ways of acting express this in the ways resources of the task are utilised, which manifests itself in the courses of action. Material products and new possibilities for action create new situations. The outcomes of action may also change orientation.

5.4 Results of the BWR study

In the BWR study we again focused on disturbance handling. Diagnostic judgement in a disturbance situation was defined, as before, as a combination of diagnostic and operative actions, which require the construction of an interpretation of the state of the process. The process may be re-stabilised and a new goal with regard to the operating state may be defined on the basis of an interpretation of the situation (Norros & Sammatti 1986, Hukki & Norros 1993). As an extension to the earlier studies we aimed at a more detailed description of the actual dynamics of the diagnostic judgement process in disturbance handling. We assumed that the distinction between the actual and the potential levels of action could provide a tool for explaining the construction of actions in particular situations.

A comprehensive simulator study was designed in cooperation with the power plant. It included a series of simulator experiments, with pilot, main and validation experiments. In the pilot phases the method for the analysis of action was developed. A further intention was to shape the analysis method into a tool to be used in simulator training. In the following we shall describe the method and the results of the main experiments in which 11 NPP crews took part. The results have been summarised in earlier papers (Hukki & Norros 1997, Hukki & Norros 1998, Norros & Hukki 1995, Norros & Hukki 1997). The detailed results have not been published before.

A prerequisite for the analysis was, of course, the formative modeling of the situation. In the studied disturbance situation the task of the crew was to identify the state of the process after an evident disturbance that caused a loss of feed water and a critical lowering of the level of coolant in the reactor tank with the possible consequence of overheating the reactor. The disturbance situation was modeled according to the principles of the *functional constraint-oriented analysis of situations*. The first level model of the situation is depicted in Figure 15. According to our modeling technique we also prepared critical information tables and tables for the analysis of the diagnostic actions indicating the usability of operating methods with regard to the two main control tasks (level control, control of residual heat removal).

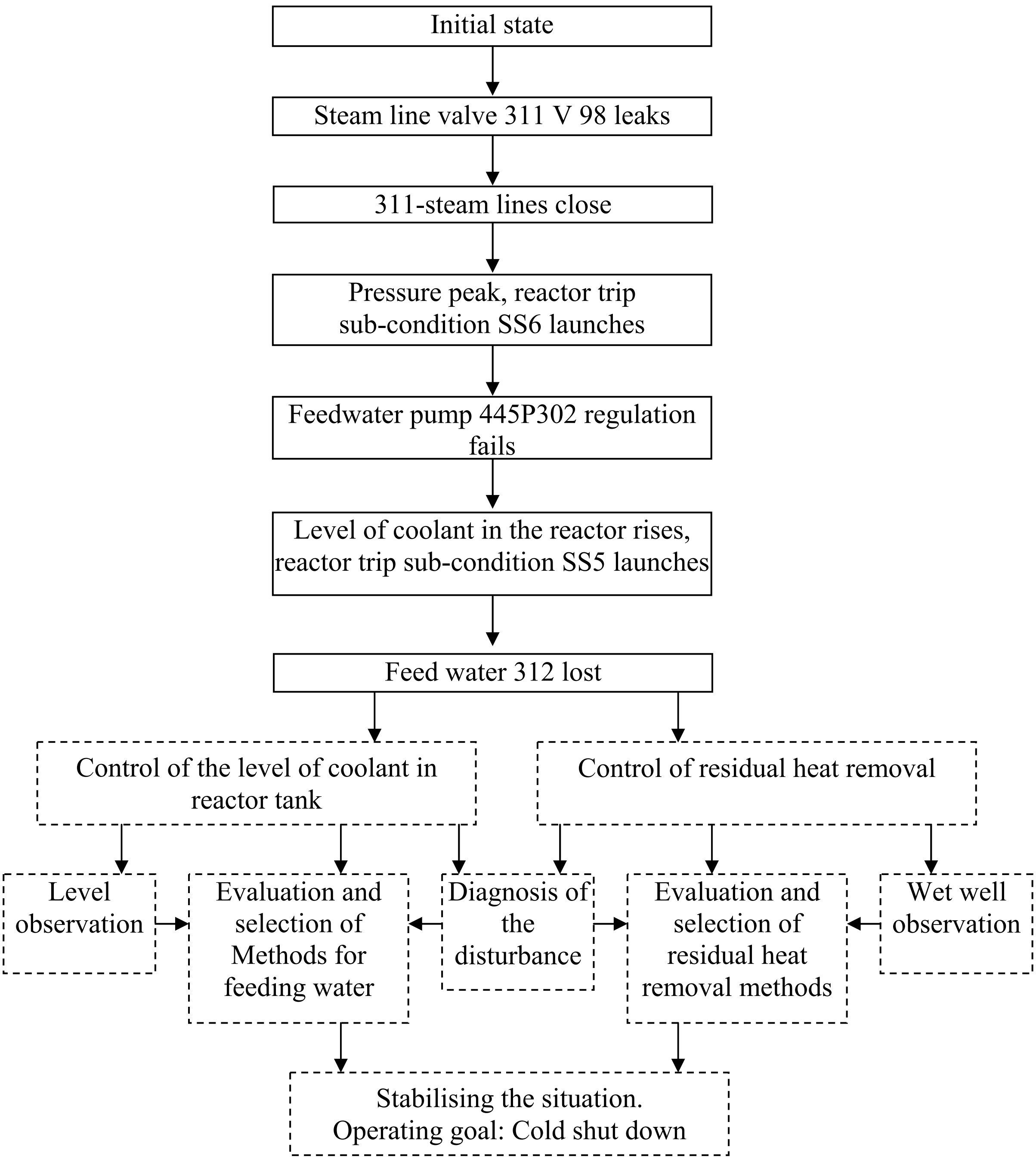

Figure 15. Functional modeling of the decision-making demands in a loss of feed water disturbance. The solid lines refer to process events, the dashed lines to operator actions (Norros et al. 1997).

All crews of the plant, each consisting of four operators (chief supervisor and reactor, turbine and field operators), performed the experimental run, which was the same for each crew. The experimental session included three phases:

Interview of the operators. Before the experimental run each operator of the crew was interviewed concerning his conceptions of the plant process, process control activity in general and his own ways of acting. The interview was tape-recorded. This data has not yet been analysed.

Task performance in the simulator. The task performance lasted 1–2 hours. During the experimental run the following data was registered: simulator logs of process events; simulator logs of operations carried out by the operators; videotaped performance including operators' communications (later transformed into written protocols); expert observations of the crew's disturbance handling using prepared note sheets.

Debriefing. After the run the operators had a chance to comment on their performance and present arguments concerning their decisions. The functional model of the decision-making demands was used to guide the discussions.

The collected material was analysed using the models of the disturbance as reference. The analysis consisted of three phases:

- *Description of the courses of action.* The operators' actual diagnostic and operational actions and the time of their occurrence were indicated.

- *Analysis of the ways of acting.* According to the conceptual model of situated action (Figure 13), way of acting was defined as a regular mode of acting that expressed the subject's way of taking into account the possibilities and constraints of the task in relation to the goal in the particular situation.

- *Explaining the dynamics of situated action.* As an operational expression of the subject's framing of the object of activity in the particular situation, way of acting was assumed to explain the dynamics of the performance. This assumption was tested in the third phase of the analysis by relating the result of the analysis of ways of acting to the observed courses of action.

Description of the courses of action

According to our earlier concept (Hukki & Norros 1993, Norros & Sammatti 1986), diagnostic judgement in disturbance handling was decomposed into the following main subtasks: search for information, diagnosis, setting of operational goals and choosing methods for stabilisation of the process. Communication was added as a co-operatively oriented task that was comprehended as a resource in the fulfilling of the process control tasks. Concrete criteria for the observation of the fulfilment of these tasks were defined on the basis of the reference models of the disturbance situation. The tasks were thereby connected to their functional significance for the BWR process. The contextualised description of the disturbance handling tasks was used to construct a timeline of each crews' disturbance handling (the sub-tasks are indicated on the y-axes of Figures 16 and 17).

A wide variance was observed with regard to the diagnosis of the problem and the choice of operational methods. Timing of operations also varied considerably. Thus, the task appeared to include many degrees of freedom, which were exploited by the crews.

When we compared the crews' task performances some characteristic differences became evident. First we found that, in the early phase of the disturbance, either the crews directed their attention to identification of the process situation, or they focused on operations. This initial performance preference was interpreted as an indication of a basic framing of the task and it was utilised as a criterion according to which the crews were classified.

Two groups of equal size were formed. The crews' further task performances were then analysed within both groups. The courses of disturbance handling of these two groups were summarised. The results are depicted in the two Figures 16 and 17. Figure 16 demonstrates the courses of action of those crews that focused first on diagnosis and Figure 17 the courses of action of the crews that focused first on operations. The observations of the characteristic common features of the crews in these two groups are given Tables 10 and 11.

The crews manifested two distinct performance patterns, differing with regard to the initial task preference (diagnostic or operative). The type of the course of action correlated with the type of operational choices, with the operational relevance of outside communication, and with the use of procedures. As the differences in the courses of action of the crews appeared to form clear patterns we interpreted that they would reflect two generic ways of acting in disturbance situations.

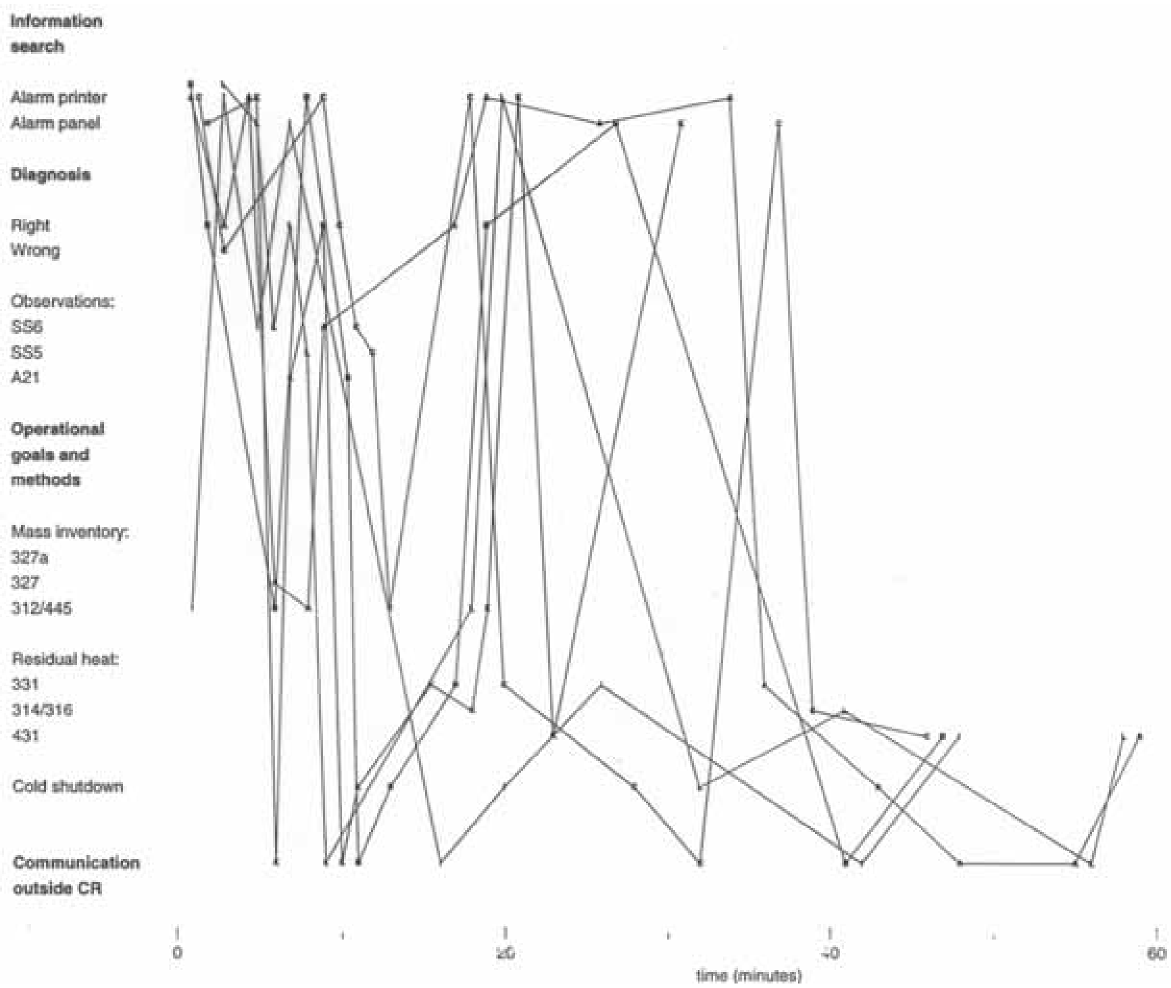

Figure 16. Courses of action of those crews that focused first on diagnosis i.e. crews A, B, C, I, K, L. On the y-axis different diagnostic, operative and cooperative actions are indicated. X-axis represents time in minutes.

Table 10. Characterisation of the courses of action of control room crews that initially preferred concentration on diagnostic activities.

Characteristics of the courses of action when focusing on ***diagnosis*** *(A, B, C, I, K, L) (Figure 16):*

In the beginning of the disturbance situation, the crews focused on *diagnostic actions*. These included information search, critical observations and diagnostic hypotheses. Operational actions were taken thereafter. (Crew I was included in this group due to its strong emphasis on diagnostic activity in the initial phase of the disturbance although one crewmember had rapidly restarted the feed water pumps.) All crews conceived the nature of the disturbance no later than 11 minutes into the disturbance, including also the second diagnosis of the crew C. This crew initially made an incorrect assumption of the location of the leak.

After conceiving the disturbance situation the crews typically took the decision to run the plant to cold shutdown. Only in two cases were the operational actions concerning residual heat taken before this decision. On average, the shutdown decisions took place earlier than the corresponding decisions of the other group of crews.

As to the *operational methods*, these crews aimed directly at restarting the feed water pumps (312/445) for maintaining mass inventory, and only one crew in this group utilised auxiliary feed water pumps (327). The use of the latter system is a generally valid method for maintenance of mass inventory. However, in this case only the two 327-pumps that provide cold water were available. Utilisation of these pumps causes unwanted temperature transients in the hot pipelines and therefore their use should be avoided if possible. Due to this, the utilisation of these pumps is budgeted according to the safety technical specifications. The reactor water purification system (331) was usually used for uprated heat transfer, but due to its insufficiency other means had to be considered, as the crews of this group did. All crews except one, K, tried to avoid the use of the relief system (314/316) due to the high temperature and probably increasing trend in the condensation pool, and attempted to seek other means to take care of residual heat. Crew C preferred the optimal method, the normal condenser system (431), for removing residual heat. All crews used this method as the last choice, usually after having discussed the possibility with the trainers.

Regarding the *utilisation of procedures* during the task performance, three crews utilised the symptom- based emergency operating procedure (EOP) immediately for controlling the operation of the safety systems.[6] Two crews, C and K, had the procedure available but there was no indication that it was used, and crew A did not take up the procedure.

Regarding *cooperation* it was found out that the crew C made only one contact outside the control room. All other crews made two contacts. In 9 out of 11 contacts the discussions appeared to trigger either diagnostic or operational decisions within the crew.

[6] The utilization of procedures and the way of their use was registered during the observation. This information is not indicated in the Figures 16 and 17.

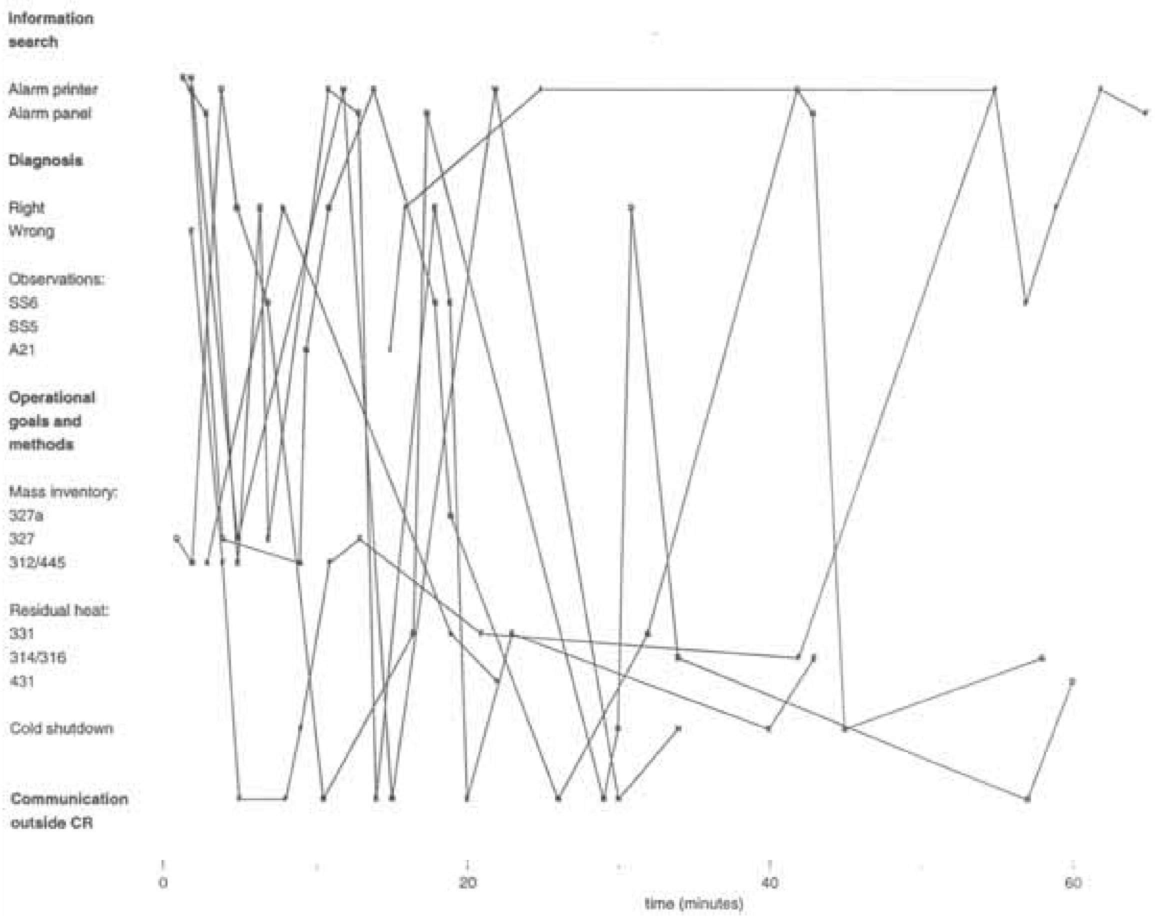

Figure 17. Courses of action of those crews that focused first on operations i.e. crews D, E, F, G, H. On the Y-axis different diagnostic, operative and cooperative actions are indicated. X-axis represents time in minutes.

Table 11. Characterisation of the courses of action of control room crews that initially preferred concentration on operational activities.

Characteristics of the courses of action of crews that focused first on ***operations*** *(D, E, F, G, H) (Figure 17):*

These crews typically initiated their task performance with *operations*. The interpretation of the situation was implicit. An indications of this was that the crews made only very few critical observations of the state of the process. A more explicit analysis of the nature of the disturbance took place within about 20 minutes, after the first stabilisation measures had been initiated. The crew F did not succeeded in forming a shared adequate conception of the situation until around 58 minutes into the disturbance. The crews made their decision to bring the process into cold shutdown on average later than those in the diagnostically oriented group (with the exception of the crew F that had a false diagnosis of a leak). Typically, the decision was taken only after starting to take care of the residual heat.

Regarding the choice of *operational methods* all the crews utilised the auxiliary feed water system (327) for maintenance of feed water, notwithstanding the resulting unwanted temperature transient. They also made preparations to take the feed water system (312/445) into operation. The crews G and H had problems in starting up the 327-pumps, which clearly hindered their task performance. The crews used the reactor water purification system (331) for uprated heat transfer as a first method to cope with residual heat. After noticing its insufficiency in this case, half of the crews, D,E and G, turned to the conventional method, the relief system (314/316), without paying attention to the safety-related restrictions of its use in this particular case. No crew prioritised the most optimal method for removing residual heat, restarting the condenser system (431), and only one ended up with this solution as a final possibility, after consulting the trainers.

The crews made use of the symptom-based emergency *operating procedure* immediately to control the operation of safety systems, except for the crew H that turned to them somewhat later, 23 minutes into the disturbance.

With regard to *cooperation* most crews made two contacts outside the control room, crew D three times and crew G only once. Only in four out of 10 times did the discussion lead to diagnostic or operational decisions. In the crews F and H some of the crew members and their chief supervisors had different opinions about the nature of the situation but the deviations in the conceptions remained implicit and were not discussed within the crew during the disturbance handling. The performance of these two crews was clearly divided. (Upper case letters in Figure 17 indicate the chief supervisor's actions.) The chief supervisor of the crew H was busy with problems in starting the 327-pumps, and did not make explicit his comprehension of the global situation. As a consequence half of the crew members operated practically independently (lower case letters)

Analysis of the crews' ways of acting

In order to identify possible differences in the crews' habitual ways of acting the very concept had to be operationalised and criteria defined for their identification from empirical material. In the following we shall present the conceptual criteria that were used in the analysis of the crews' actions.

Way of acting was conceived as a generalised mode of behaviour that expresses the actor's personal comprehension of the relevance of the situation-specific constraints and possibilities of the task in relation to achieving the situated goal. It denotes the personal sense that these constraints and possibilities have for the actor in this task. Way of acting could be inferred on the basis of how the operators make use of the available resources, given that there is knowledge about the significance of these resources for the attainment of the critical objectives and functions of the power process.

According to the general ecological perspective that we advocated, the actor and his/her environment constitute a system. The functioning of the system manifests itself as interaction between the actor and the environment, which always takes place in a particular situation. The foremost criterion for evaluation of action is the *situational appropriateness* of this interaction (Hukki & Norros 1993). Situational appropriateness expresses *adaptability of the human-environment system* and promotes *continuity of interaction and survival of the system.* We had developed models of the domain and situations for the analysis of what possibilities the environment affords for appropriate action. But for the analysis of the situational appropriateness of actions we needed to define the actors' propensity to make use of the environmental potentials. Drawing on the activity theory we considered orientation as the relationship of the actor to the object of action in a situation. This conception was thought to provide a possibility to define these subjective potentials.

We began to seek generic characteristics of orientation that could be considered to be important determinants of situational appropriateness of action and, thus, could serve as an evaluation basis for the ways of acting. The basis for the definition of these characteristics was drawn from the ideas of Ewald Ilyenkov regarding human judgement (Ilyenkov 1977, Ilyenkov 1984, Norros 1988) (see Chapter 4). We interpreted Ilyenkov by stating that judgement is qualified with a dialectical relationship between the particular and personal on the one hand, and the general and societally given, on the other. This tension constitutes the basis for construction of knowledge of the environment and for intelligent action in the environment. Consequently, in the orientation towards the environment two generic tendencies were considered to be effective simultaneously. On the one hand, it is necessary to identify invariance's and general features in the situation and, at the same time, it is also essential to take into account the specificity of each situation and to pay attention to changes in the situation. Balancing between these two demands was seen by us to reflect what we called the *tendency to form a coherent interpretation of a situation.* This feature was adopted as one aspect of orientation and was thought to reflect the tendency to generic comprehension and to facilitate continuity of action in changing situations. We found support for the above described solution from Harré and Gillet (1994), who had considered an equal tendency to be important for successful action.

The other tendency, which we named *situativeness of interpretation*, was seen to refer to attention to particularities of the actual situation. An interpretation of the situation requires both. We also identified a third tendency, that of *reflectivity*, which was seen to refer to control over one's action. It was not used in the analysis due to lack of empirical material for its elaboration. Consequently the first two orientational tendencies were interpreted as general evaluation categories for way of acting.

An important cornerstone in the further operationalisation of the way of acting concept was the idea that action is organised with reference to its outcomes. In the case of process control, the task consists of continuously diagnosing the state of the process and of carrying out regulation and control operations. Moreover, the processes are usually extensive and complex, and therefore shared cooperative activity is necessary. We defined way of acting with regard to both the process control tasks and the cooperation needed for the realisation of these tasks.

As a result, the conceptual method for inferring ways of acting was defined with the help of three categories:

1. Orientation: coherence (C) and situativeness (S) which constituted the evaluative dimensions for ways of acting;
2. Task demands: process control and cooperation
3. Available resources: process information, procedures and the operator team.

Through combining these categories we derived items for the evaluation of the way of acting with regard to the two evaluative dimensions. The items constituted of operationalisations of the crews' utilisation of the available resources that were drawn from the material of the crews' courses of actions, and they were interpreted with reference to models of the studied disturbance situation and to the operators' own accounts. Unfortunately we faced difficulties in finding adequate contextual anchors for the operationalisation of the use of procedures. The logic of determining the items is presented in Table 12. These items were the sought criteria that would provide the basis for the evaluation of the potential for situationally appropriate action.

A three-step scale was utilised in the actual evaluation of the operators' ways of acting with respect to the evaluative dimensions (coherence and situativeness). The scales that related to the *coherence* of diagnostic and operative interpretations of the process were constructed on the basis of our earlier results regarding the informativeness of process information (Hukki & Norros 1993). The inferences were defined, as process dynamic when functionally informative process information was clearly utilised and not process dynamic when such information was clearly not utilised. The evaluation "between" was used when there were difficulties to identify the basis of inference. The coherence of interpretations in relation to cooperation was conceived to become overt in the intention to create common interpretation of the situation through communicating within the crew for coordination. The scale we used was "explicit", "partly explicit" and "implicit" communication. In the case of items related to *situativeness* of interpretation we classified actions of the crews with regard to their activeness (active, intermediate, passive) of focusing and searching for available information from the information and control panels or through communication with other members of the crew.

Table 12. The logic of defining the items used in the evaluation of the chief supervisors' and the crew members' ways of acting. The 17 items signified with a dot (•) in the table, were operationalisations of the utilisation of available resources. The items were grouped into four task-related demands of way of acting in process control. These are indicated in the bottom row.

	Generic orientational tendencies							
	Coherence of interpretations				Situativeness of interpretations			
	Task				Task			
	Process Control		Co-operation		Process control		Co-operation	
	Diag-nostic	Oper-ative	Com-muni-cation	Co-ordi-nation	Diag-nostic	Oper-ative	Com-muni-cation	Co-ordi-nation
Resources								
Process information	•	•			••••	•••		
(Procedures)								
Team			••	•		•	••	••
Demands of way of acting in process control	=> Coherent basis of inference		=> Communication of the basis of inference for co-ordination		=> Search for available process information		=> Attention to the team situation	

An example of a *diagnostic* item expressing *coherence*:

- checking automatic safety functions

An example of a *diagnostic* item expressing *situativeness*:

- searching for process information

An example of an *operative* item expressing *coherence*:

- Ensuring the availability of methods beforehand

An example of an *operative* item expressing *situativeness*:

- Taking the operational restrictions into account

An example of a *communication* item expressing *coherence*:

- Clarity of communication

An example of *communication* that expressing *situativeness*:

- Reporting personal observations

An example of a *cooperative* item expressing *coherence*:

- Ensuring that tasks are completed

An example of a *cooperative* item that expressing *situativeness*:

- Taking the other shift members' opinion into account in interpreting the situation[7].

[7] An elaborated list of evaluation criteria for habits of action and an analysis of the functionality of the tool is provided in Norros, L. & Nuutinen, M. 2004. Performance-based usability evaluation of a safety information and alarm system. Submitted.

The whole set of items was used for the evaluation of the chief supervisors' ways of acting. When analysing the other crew members' actions only the items referring to cooperation were used. The results of the analysis were presented to each crew separately and discussed thoroughly with the crew and the instructor. After the acquired feedback the evaluations were summarised. The four demands of way of acting in process control were used in the classification as Table 13 indicates.

Table 13. Evaluation of the crews' ways of acting (based on the evaluations of the chief supervisor's actions) with regard to the demands of way of acting two of which expressed coherence (C) and two situativeness (S) of interpretations. Three-step scales express the extent of coherence or situativeness, respectively.

Crew	**Way of acting in process control**		**Way of acting in co-operation**	
	Coherent basis of inference (C)	Search for process Information (S)	Communication of the basis of inference (C)	Attention to the team situation (S)
A	Process dynamic	Active	Explicit	Active
B	Process dynamic	Active	Explicit	Active
C	Process dynamic	Active	Explicit	Active
I	Process dynamic	Active	Explicit	Active
D	Not process dynamic	Intermediate	Explicit	Active
E	Not process dynamic	Intermediate	Explicit	Active
F	Not process dynamic	Passive	Explicit	Passive
K	Not process dynamic	Intermediate	Partly explicit	Active
G	Unidentifiable	Intermediate	Implicit	Passive
H	Unidentifiable	Intermediate	Implicit	Passive
L	Unidentifiable	Active	Implicit	Active

The results concerning the demands of the *coherent basis of inference* verified our earlier result (Hukki & Norros 1993) that crews have typical differences in their bases of inference. Drawing from the crews' communications during action, from their accounts of their action in the debriefing session, and from the crews' actual behaviour, it was possible to demonstrate that the crews A, B, C, and I clarified for themselves the disturbance phenomenon in process-dynamic terms. This became manifest in the courses of action through the chief supervisors' attempts to find and explain relationships between the observed critical process events. Furthermore, the crews evaluated optional operational methods in the global production context by referring to the process-dynamic nature of the situation.

Some other crews, D, E, F and K, did not make process dynamic inferences. From further analysis of the communications and accounts of these crews we inferred that they attempted to create coherence of action through other means. Typical for these crews was the application of a ready disturbance model, mainly a habitual procedure or a fixed operational plan. The crews judged the situation with the help of this model and their operating actions were planned according to it. The use of this method by these crews did not appear to demand analysis of the relationships between critical process events.

Regarding three crews, G, H and L, the communications and accounts of the chief supervisors were very scarce, due to which it was impossible to identify the crews' basis of inference.

The second demand of way of acting*, search for process information,* reflected situativeness of the chief supervisor's interpretations in relation to the process. It was evaluated on the basis of a set of items indicating activeness of the chief supervisor both in using different sources of information in the determination of the process situation and in his critical evaluation of the situation specific usability of operational methods. Table 13 indicates that crews that were rated as expressing a process dynamic basis of inferences typically paid active attention to the process situation, whereas those not making process dynamic inferences were less active, or even passive in this respect.

The third demand of way of acting, *communication of the basis of inference for co-ordination*, referred to cooperation. It expressed the chief supervisor's activeness in communicating his own basis of inference in diagnostic and operational decisions with the aim to create common awareness of the situation and to coordinate the crew's actions. As Table 13 indicates, most chief supervisors communicated their interpretations to the crew, independently of the basis on which these inferences were made. However, the chief supervisors of the crews G, H and L did not make their interpretations explicit. The interpretations were only partly explicit in the case of crew K.

Attention to the team situation was a demand of way of acting that referred to situativeness of interpretations with regard to cooperation. In assessing this feature we utilised items that expressed the efficiency of the chief supervisors to take account of the crew members' task load, or expressed how efficiently they could utilise the crew members' inputs in their own decision making. Most chief supervisors could be evaluated as active. Only three of them, F, G and H were assessed to be passive in taking account of the team situation.

In conclusion, particular patterns could be identified in the crews' ways of acting. First, it became evident that process dynamic inferences appeared to correlate with high attention to process situations. This connection was interpreted to indicate a *constructive way of acting* in process control (crews A, B, C and I). When process dynamic inferences were not made there was a lower level of attention to the situational process information. We characterised this behaviour pattern as a *model-based way of acting* in process control (crews D, E, F and K). Generally, effective utilisation of team resources was typical to both of these patterns. Eight of the eleven crews could be identified to represent one or another of these two patterns. Beyond these major patterns, further characteristics of the way of acting could be identified. Manifesting principally the model-based way of acting, the crew F expressed lack of situativeness both with regard to the process and to the cooperative situation. Furthermore, with regard to the crews G, H and L the basis of inference remained undefined due to the lack of communication of inference basis.

Explaining the dynamics of the crews' situated action

In the last phase of analysis the evaluations of the crews' ways of acting were compared with the courses of action of each crew. The aim was to determine whether a meaningful relationship could be established between the identified ways of acting and the actual courses of actions. Due to the theoretically assumed relationship with the subject's conception of the object of activity, orientation, way of acting was seen to have a regulating and sense-making function with regard to action. Thus, the way of acting could be interpreted as explaining the dynamic organisation of the action in particular situations.

As was indicated earlier, we found two typical patterns in the courses of actions. We observed that the first group of crews (A, B, C, I, K, and L) preferred to clarify the nature of the disturbance situation first, and, on this basis to set the operational goals and choose the operational methods. This performance pattern was in accordance with the constructive way of acting that was identified to characterise the crews A, B, C and I. These crews constructed situatively a process-dynamic interpretation of the state of the process. The adopted process-dynamic way of thinking provided a coherent and sufficient frame for action. It corresponded well with the approach that was applied in the design of the procedures, but the crews may not have found it necessary to consult the procedure in the sense of directly following it. Process-dynamic interpretations were combined with critical evaluation of the situation, which became manifest in the choices of operational methods. Consequently, the crews did not exploit the generally valid solutions that had negative long- and short-term safety effects but, instead, preferred solutions that were particularly suitable in the prevailing circumstances. For example, the crews did not readily exploit the auxiliary feed water pumps but preferred to restart the normal feed water, which was available notwithstanding the disturbance. They also took account of the high temperature in the condensation pool and anticipated its increasing trend. Therefore they did not transfer residual heat through this system. One of the crews even decided to apply the, at the time, unconventional but advantageous option of using the normal condenser system for transfer of residual heat. Other crews did the same with assistance. Thus, optimal operational choices became possible through understanding the nature of the particular disturbance situation.

Process-dynamic interpretation of the situation pre-requires efficient utilisation of the available information resources. This fact became particularly evident in the case of crew C. This crew was able rather quickly to correct an initial deficient assumption of a leak, as this was not in accordance with the observed process state. Typical for the crews A, B, C and I who represented the constructive way of acting was an active communication of inference basis and continuous attention to the crew members' task load. Correspondingly, their courses of performance were well coordinated and fluent. The utilisation of the personnel outside the control room for decision making was another sign of the crews' appreciation of the use of cooperative resources.

The basis of inference of the crew L remained open in the analysis. This is related to the methodical fact that the conclusions about the crews' interpretations were based on the crews' communications during the disturbance situation, and this crew was poor in communications. However, the crew was attentive and critical towards the process situation, which was found to correlate with a process-dynamic inference basis. Furthermore the course of performance of crew L was similar to that of the crews A, B, C and I, which also provided a reason to assume that the crew probably constructed process dynamic interpretations as did these other crews.

The course of action of the crews D, E, F, G and H was different. These crews focused immediately on operations for stabilising the process. The observed courses of actions may be explained through the model-based way of acting of these crews. The central feature of these crews' ways of acting was that the situation was structured with the help of a ready disturbance model. This way of acting was explicit in the case of the crews D, E and F, and could be inferred indirectly in the case of crews G and H. All these crews were less attentive to the particular features of the process situation. Crews chose generally usable methods to maintain mass inventory and to cope with the residual heat. By doing this they did not take into account the long- and short-term negative safety effects of their use. Consequently the operations were not situatively most appropriate. The fact that these crews were inclined to make use of the emergency operating procedure that is designed to provide a universally applicable method to check the activation of the safety functions, may indicate the necessity for that kind of reasoning, which otherwise was not typical to the crews. It should, however, be considered that in this study the data was not sufficient to make reliable inferences about the crews' reasons concerning the use of procedures. Cooperative decision making was well coordinated with the aid of the performance model that was known to everybody.

Possible weaknesses in the model-based way of acting also became manifest. In the case of crew F the chief supervisor became fixed with a conception of the disturbance at the very beginning of the simulator run. He did not notice that the interpretation of the situation was deficient due to poor attention to process information. Identification of the discrepancy between the assumed and real situation was also hindered through deficient use of the other crew members' opinions about the situation. The source of the problems in this case seemed to be the failure to act situatively both with regard to the process and to cooperation.

The task performances of the crew H, and also the crew G, were somewhat scattered, which was evidently due to problems in the starting up of the auxiliary feed water pumps. This obstacle in the use of the normal stabilisation method clearly distracted the organisation of the task performance, indicating that the aimed principle to structure the situation was probably disturbance model-based. In the case of crew H this conclusion gained further support from the fact that clearly available information was not utilised for inferences concerning the process situation. A particular feature of both of these chief supervisors' ways of acting was a deficient utilisation of cooperative resources as an aid in the structuring of the situation and in the reorienting in the selection of the stabilisation method.

The crew K was the only one that did not demonstrate a consistent connection between way of acting and the task specific course of action. This crew's course of action was diagnostically driven, but the way of acting was evaluated to be model-based.

The results obtained in the three-phase analysis of the operator crews' decision making are summarised in the following Table 14.

Table 14. Summary of the results of the analysis of 11 NPP crews' action in a disturbance situation. The crews are indicted by capital letters.

Successive steps of evaluation			
Description of the course of action	**Way of acting**	**Dynamics of situated action**	**Expected efficiency of performance**
ABCIKL:diagnosis is connected with situation specific operational choices.	ABCI: constructive	ABCI and L: in this situation constructive way of acting oriented task performance towards diagnosis-driven interpretative operational practice.	High adaptability in novel situations through efficient utilisation of available information and cooperative resources. Assumed to promote learning.
	LGH: unidentified		
DEFGH: stabilisation connected with utilisation of standard operations.	DEFK: model-based	DEF and GH: in this situation the model-based way of acting oriented task performance towards operations with the help of standard methods.	High efficiency of stabilisation of the process in expected situations. Vulnerable in novel situations, and for distractions. Also vulnerable for deficits in co-operation.
		K: the observed way of acting was not consistently connected with task performance in this situation.	

The study described above described study was our first attempt to define criteria for ways of acting. Later, based on the same data, we comprehended the method further and developed a more elaborated set of the criteria (Hukki & Norros 1998). A more practical version of the method was prepared for the nuclear power plant to be used in the evaluation of the crews' performances during simulator exercises. The method and criteria were also used in a validation study were the usability of an operator aid for emergency control was studied (Norros & Nuutinen 1999, Norros & Nuutinen 2004).

5.5 Conclusions for further studies

Through the three studies on NPP operators' handling of disturbance situations we have attempted to demonstrate the nature of diagnostic judgement as the central demand of process control work that exemplifies the core task of nuclear power plant operation. In the first study an information-processing model of the task was used. Deviations from a predefined ideal performance were classified as different kinds of decision-making errors. Our theoretical assumptions of the nature of judgement processes gave us grounds to hypothesise that the differences in error profiles were a sign of the crews' different approaches to the disturbance-handling task. Verifying these assumptions in further studies required a change in research approach. The assumption concerning the orienting role of the object of activity in situated action was adopted from the cultural-historical theory of activity. The diagnostic judgement was seen to express the actors' interpretations of the situational goal and conditions of action in relation to the more global demands of the activity.

In the two later studies reported in this chapter we utilised the orientation-based methodology and were able to find support for the assumptions drawn from the human error experiments. We found out, first, that the crews appeared to utilise differently the informative potential of the available process information during a disturbance situation. The differences in the information that the crews accounted as relevant (functional or locative informativeness) were interpreted as a manifestation of assumed differences in the framing of the process. Second, we also discovered that the situativeness of orientation was a significant feature of way of acting. Using the two orientational tendencies, which we named coherence and situativeness of interpretations, as underlying evaluation dimensions two basic ways of acting were identified, the constructive and the model-based way of acting. Third, we found that there is a meaningful relationship between the crews' ways of acting and the particular, situation-specific courses of their task performances. It is the interplay between the process situation and the operators' accounts of it, defined through the way of acting that produces the particular course of actions.

The results of Di Bello support our results of the existence of the observed ways of acting (Di Bello 1997). Döös's findings from the domain of automatic manufacturing also suggest that differences in the operators' stance to their work have consequences for the operators' ways of working (Döös 1997). Elaboration of the different ways of acting is also possible for example by including accounting also energetic-emotional aspects of orientation as evaluation categories (Norros & Nuutinen 2002). Inclusion of energetic-emotional aspects in the methodology would be a necessary extension of the method, because there is clear evidence that problems in optimal mobilisation of resources is a genuine problem both in situations of low and high external demands of action.

We claimed that the foremost criterion for the evaluation of performance is its situational appropriateness. In the BWR experiments it was decided not to define the adequacy of performance in terms of the successfulness of the end-results. It was reasoned in the plant that an explicit evaluation of the adequacy of performance could have facilitated the interpretation that the observed differences indicate individual operators' personal abilities. By developing the concept of way of acting we aimed at analysing practices that have been learned in the community and that may be improved and reshaped through reflection, which this kind of analysis of actions should promote.

Our results allowed conclusions regarding the expected efficiency of the different ways of acting (see Table 14 in the previous section). First, the results supported the conclusion that the characteristics of the way of acting are related to the *adaptability* of performance. The constructive way of acting that is based on process-dynamic inferences provides higher adaptability in a particular situation, because the related task performance does not follow a predefined course of actions but is constructed according to the situation. The crews' actions were situatively appropriate. In the study we gained support for claims of the efficiency of the constructive way of acting. We observed that two constructive crews could recover from an initially false hypothesis about the nature of the disturbance. By contrast, another crew that was characterised by a model-based way of acting tended to be fixated on an incorrect interpretation of the situation. As the inferences in this way of acting are coupled with less active search for process information, the observed tunnel-effect may occur. A corresponding problem was identified in an earlier study with regard to one of those crews that was classified as the least functionally oriented on the basis of a weak use of process dynamic functional information. (Hukki & Norros 1993).

Situativeness appears to have general relevance to the efficiency of action. Besides the tunnel effect, another typical phenomenon, distraction of activity due to external interruptions, has found to cause severe difficulties in the control of complex environments (Mandler 1982, Weick 1993). In our material the task performances of two crews, which manifested the model-based way of acting, were distracted by interruptions of the normal expected flow of events. It can be argued that re-orientation in the situation and reallocation of resources is less easy for those crews whose actions are organised according to the model-based, less situative way of acting.

In an analysis of cooperative decision making in the cockpit Orasanu and Salas (Orasanu & Salas 1993) demonstrated the significance of the pilot's communication of his inference basis for the efficiency of the crew's performance. According to our results, if combined with model-based inferences chief supervisors with deficient explication of the basis of inference and deficient use of other team members' contributions, may be particularly prone to operating problems. It was observed that in operator crews with a long common work history, shared decision making may be coordinated even without communicating the basis of decision making, if the basis of inference was process dynamic. Nevertheless, we think that implicit decision making is a source of uncertainty and potential problems. Problems may also arise if, in a disturbance situation, the staffing incidentally deviates from the usual.

The results allow even more long-reaching conclusions. It may be assumed that if the differences in the ways of acting in disturbance situations reflect more general attitudes towards the object of activity, the operators' actions could also be expected to have characteristic differences in normal everyday work. It may be assumed that if process events are conceived as predictable and repeating themselves they would probably be coped with routine. If the process is perceived as particular and unique, it could be assumed to raise questions and a need for information and contextual explanations of the observed phenomena, in any operating state of the process. (Norros 1995). As a consequence, new information of the process would be created, and learning from experience would take place. Therefore it may be assumed that besides being more effective through contributing to the appropriateness and adaptability of performance in a situation, the constructive way of acting would also promote *learning from experience.*

In our conclusions from the earlier error study (Norros & Sammatti 1986) we stated that a process dynamically oriented way of acting may have been typical for the more efficient crews both in a less and more complex disturbance situation, even though the benefits of this way of acting became overt only in the more complex situation. This assumption reflected our ecologically oriented conviction that the domain and the task demands do not alone determine action in a situation, even though action certainly differs depending on the situational constraints. Furthermore, there is important variance in action that originates from the differences in the actors' ways of taking into account the specific environmental features. The situative appropriateness is determined by the ways of acting. Our interest was to find such generic features in action that may be responsible for differences in ways of acting.

In our method we made the distinction between the two aspects of action, the actual situational realisation of action, and the dispositional potential or mode that the very action manifests. This distinction was expressed in the concepts of *course of action* and *way of acting.* The methodological advantage of this distinction is that it allows a genuinely ecological analysis of action. Action is analysed as an interaction between the person and the environment in a particular situation, which is shaped by the personal learned propensities to take into account the possibilities of the environment. The possible significance of the environmental features for the behaviour of the actor is in the analysis comprehended by the modeling of the constraints of the situation. The distinction of actual and potential also offers a developmental point of view to action, as it enables the analysis of the dynamics of situated construction of courses of action.

Analyses of both disturbances and normal daily actions are equally interesting and informative from the point of view of understanding the regularities of action. Normal situations and disturbances reveal different kinds of constraints for action but they do not relate one-to-one with routine and reflective actions, respectively. People may act reflectively in normal daily routines, as they may act routinely in demanding problem situations such as disturbances.

Our results from the NPP studies encouraged us to continue to develop our method. It became clear that analysis of behaviour from the outside, as responses to events that the investigator defines as significant, does not lead us further. When reflecting on our NPP studies it becomes evident that we were still not able to acknowledge fully the principle that the actors' own accounts of their behaviour should be the starting point of the analysis of actions. Thus far we had not paid sufficient attention to the meaning and personal sense of the situations and the constraints. This may have been due to the practical consideration that the modeling of the very complex situations required intensive consultation with the domain experts. As a consequence the experts' point of view tended to dominate the thinking of the investigators in the analysis of the operators' actions, and the operators' personal relationships to these constraints and their reasons were not queried in detail. The deeper cause was an insufficient methodological insight into the relevance of the subject's point of view, and the lack of clarity of the theoretical concepts.

6. An ecological method for the analysis of situated action. A study in the anaesthetist's clinical practice

6.1 The core-task and how to infer its content

In the fourth chapter we defined the core task as *such content of work, characterised through the objective and the outcome-critical intrinsic constraints of activity, that the actor should take into account in all situations when determining the relevance of situated goals and conditions for the attainment of aimed objectives.*

The core task is societally and historically constituted. For example the exploitation of information-technology in work processes for improving measurements or for enhancing control and communication increases the mediatedness of work. This puts new demands on the conceptual mastery of the task and on co-operation (Zuboff 1988). The actors' conceptions of the core task of their work orient their situated actions. Therefore it is significant that these conceptions are appropriate with respect to the desired outcomes. An effective strategy for the development of work should facilitate focusing on the core task in daily actions, and encourage reflecting on its content (Norros 1998, Norros & Nuutinen 2002, Oedewald & Reiman 2003, Reiman & Norros 2002).

The Core-Task concept was developed for comprehending the often implicit and continuously developing content and demands of work. With the aid of an analysis method based of the core-task concept we aim to promote the actors' orienting towards the core task and to develop work practices. The conceptual model of the Core-Task was presented in Chapter 3 (Figure 6). The model is depicted once again in Figure 18 because in the following we are transforming this conceptual model into an analysis scheme to be used in an empirical Core-Task Analysis.

The Core-Task Analysis focuses on the actual situated actions of the actors in their work because we are interested in understanding the development of work practices. However, in this approach actions are placed in their societal and material activity-system context by means of an analysis of the meaning of actions. The context of actions is interpreted as providing the potential for the actual realisation of the activity, actions and operations.

In the Core-Task Analysis methodology we have developed a way to analyse the context both from the point of view of the social-physical environment and the learned dispositions of the acting agent. Vicente developed an appropriate approach for the analysis of complex domains (Vicente 1999). By proposing the formative approach Vicente may be interpreted as drawing attention to the potentials that the features of the environment provide for action. In order to elaborate the approach of Vicente we exploit the activity-systemic model of Engeström (1999) and create a comprehensive frame for conceiving the environment as the meaningful context of action.

Moreover, we also maintain that the subject's action should be treated in a formative way in the analysis. In other words it should facilitate understanding of the subject's personal potentials to act. The learned dispositions of the actor, i.e. his/her habits, express this perspective to action (Peirce 1998a). Habits are actualised in particular situations but refer to generic ways to relate one to these situations. Hence, habits may be seen to provide continuity to behaviour, which is necessary for maintaining an appropriate human-environment relationship. We identified habits by defining how people make use of the affordances of the environment when interacting with the environment in particular situations. Thereby we identified the active state of habit, the habit of action (thinking, cooperating etc).

To find out habitual features of practices we analyse the reasons why people act (von Wright 1998a). As an expression of the intentionality of action reasons explain action. Reasons reveal different ways to take into account the objectives of the activity and the result–critical intrinsic constraints in accomplishing the task. Knowledge of reasons provides us the possibility to develop concrete criteria of habits of action, with the help of which we distinguish differences in practices. These criteria are, further, used to draw the actors' attention to the appropriateness of their own practices.

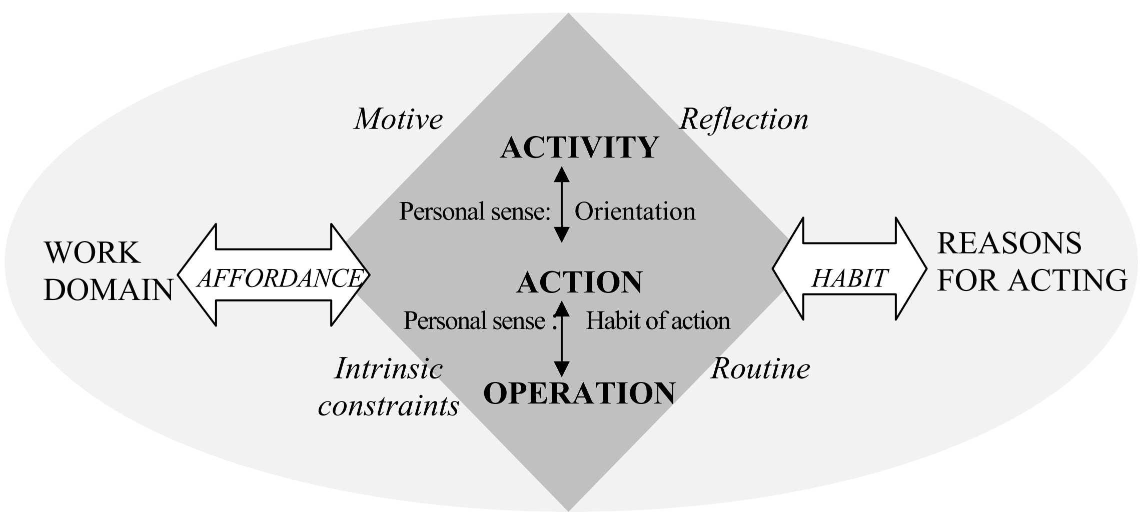

Figure 18. The conceptual model of the Core-Task Analysis (see Chapter 3).

In the conceptual model of Core-Task Analysis (Figure 18) the background oval is an illustration of the inherent potential of action, the context of actions. The concepts that are represented in this field may be used in an empirical analysis for inferring the specific content of this potential as the possible reasons for actions. The actual aspect of action is depicted in the diamond-shaped field in the centre. The concepts represented in this field refer to the actualisation of this potential in actions. The central categories of activity, action and operation were drawn from the theory of Leont'ev (Leont'ev 1978), and they are used in the analysis of actual courses of action.

There are two concepts represented in the conceptual field of actual action that require further consideration. These are *orientation* and *habit of action*. As we indicated in Chapter 3, they denote the relationship between action and activity, and action and operations, respectively (see also Figure 18). According to our interpretation of Leont'ev both these relationships reflect personal sense (see chapter 3) (Leont'ev 1978).

Leont'ev maintained that personal sense expresses *the role that the societally shared (and outcome-critical) generic meaning of the object of activity plays in defining the goals of action in a situation.* In our empirical work, we have used the notion of *orientation* to indicate this relationship. Orientation was defined as the subject's stance to the object of activity as the goal of personal situated action (Leont'ev 1978). Thus, when dealing with the rational aspect of meaning, Leont'ev makes a distinction between meaning and personal sense.

However, a corresponding distinction is not made by Leont'ev with regard to the corporeal aspect of meaning. He does not explicitly conceptualise the relationship between action and operation in his theory. We suggested that by analogy to the relationship between action and activity this relationship should also be interpreted from a meaning point of view. This relationship also expresses personal sense but in an embodied way. We introduced the concept of habit of action for this purpose. Habit of action expresses *the role that the societally shared (and outcome-critical) generic meaning of the particular environmental conditions plays in taking into account the conditions of action in a particular situation.*

We gained support for this interpretation from the pragmatist conception of habit. This notion explicitly denotes the meaning that is manifested in operational routines, and, thus, provides theoretical justification for the interpretation of operations as conveying generic societal meaning. The Gibsonian concept of affordance provides further support for this interpretation. Environmental conditions are taken into account in operations. They are meaningful, because in the form of affordances they are useful for human action (Gibson 1977). Habits of action express the personal significance, or sense, of these meanings to particular persons in specific situations.

Orientation and habit of action are understood in the Core-Task concept as psychological-concrete categories. They refer to the active state of habit (see Chapter 3) and are used in an empirical analysis of behaviour to express the potential to act that qualifies habit. This potential aspect connects the analysis of actions with the material and societal context in which the action takes place.

The Core-Task Analysis inference scheme

The Core-Task Analysis is a conceptual method that makes explicit the inferences that are needed to interpret empirical data of human behaviour from the perspective of its meaning. The aim of the analysis is to enhance understanding of the content and the dynamic construction of actions, and to provide a basis for the evaluation and development of practices.

Both qualitative and quantitative data of conceptions and corporeal behaviour may be exploited in the CTA. The inferences follow a scheme, which we have derived from the above-depicted conceptual model of the CoreTask. The inference scheme has three parts, within which the actual analysis and interpretation of data is accomplished. The inferences may be repeated several times for the acquisition of the result, i.e. a conception of the action. The inference scheme is depicted in Figure 19.

One of the basic assumptions in our analysis of work is that activity is actualised in personal action in a situation. We must therefore analyse the situation but this we do from a formative point of view. The *formative modeling of the work domain* constitutes the first part of the Core-Task Analysis. This part of the analysis is represented in the upper part of the background field of Figure 19. The modeling of the work domain represents an external analyst's point of view. We consider the work domain as the meaningful activity system context that affords possibilities and sets constraints for action in the form of *core-task demands*. These demands may be derived as the critical functions of the domain are set in relation to the interaction demands of the activity.

As the actor is intentionally directed towards the environment he takes into account the *constraints and possibilities* put by the environment. In the second phase of the inferences of the CTA we analyse the individuals' operations from the point of view of the various possible ways of taking into account the constraints and possibilities of the domain. This is the *analysis of habits*, depicted in the lower part of the figure. *Indicators and criteria of habit of action* portray what could be comprehended appropriate action. The indicators and criteria are derived by analysis of how the abductive dynamics of action, that provides the adaptability to action, may be achieved in the particular DCU environments. The required adaptability becomes visible in the real perception-action cycles under particular constraints and possibilities. In the analysis these are set in relation to each other to infer the indicators. This part of the analysis also represents an external point of view to action. The analysis is based on actual actions but aims at deriving generic features of action, habits. It defines habits as possible reasons for action in a particular work and domain.

The right-hand side of the modeling of the domain and the analysis of habits may be interpreted to relate to a functional way of modeling of the domain and action. The left-hand side refers to a sequential and causal modeling. The relationships between the elements of the scheme are indicated with two-way arrows. This should stress the fact that the analysis is not a linear process, but one that has several cycles of inferential acts.

Our analysis is restricted to working activities, and thus to the meanings that the object of activity and the activity system comprise. In a professional activity, it may normally be assumed that the actor intends to take into account the outcome-critical functions of the domain, which should be understood as historically developing intrinsic constraints. These define the outcome-critical boundaries of action that are evolving entities. The boundaries must be taken into account in the task performance by balancing between the situational constraints and possibilities of action. Hence, the critical functions may be comprehended as having *meaning* for a professional actor. The *appropriateness* of action requires, however, that these meanings are taken into account in particular situations. *Adaptability* of action may be created through abductive inferences. Appropriateness thus requires that the core-task demands are meaningful and interactions in a particular situation are adaptable.

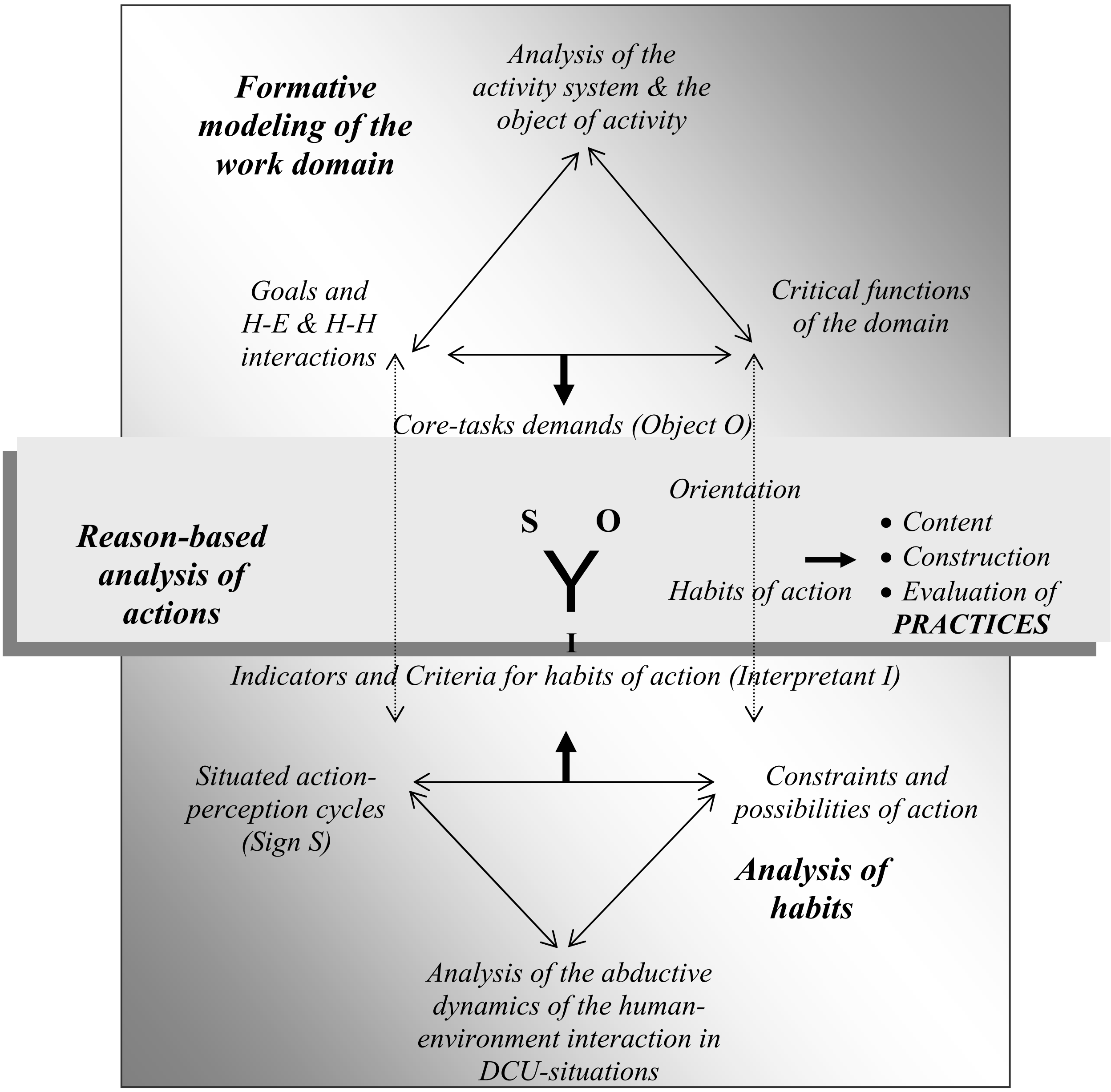

Figure 19. The inference scheme for the Core-Task Analysis of the situated actions. The two parts of the analysis are the formative modeling of the situation, i.e. analysis of the work domain as an activity system (upper part) and analysis of habits (lower part) and the reason-based inference of courses of action (centre).

However, we do not know the *logic* according to which the actor will consider these meanings, i.e. what is their *sense* to him. Thus, we may observe that the analysis of behaviour has a double perspective, the external observer's and the subject's perspective. This distinction was also pointed out by Theureau when he developed his semiotic analysis of behaviour (Theureau 1996). The investigator takes an external point of view when he focuses on the actor in the situation, and he may conceptualise the situation in the objective formative way. The result is a conception of the constraints of and possibilities for action that the actor may take into account when acting or giving his accounts concerning action. These results of the investigator express the generic meaning of the constraints with regard to the objectives of the activity. The actor's subjective point of view denotes the environment as a personally meaningful object of action. The actor faces the environment equipped with a multitude of acquired habits. The actions of the agent should not be explained as an external connection between the situational features and the observed behaviour. Instead, the investigator must make an analytical effort to become knowledgeable of the personal sense of action, usually through inquiry about the *reasons* for action. This constitutes the third phase of the inference. It is called *the reason-based inference of actions* and it is depicted in the centre of Figure 19.

In the third part of the CTA we exploit the results of the previous phases. The connection is expressed in Figure 19 by the meaning relationship model that consists of the sign (S), its object (O) and the interpretant connecting the two (symbols S, I and O). By this model the results of the first two phases of analysis are utilised in the last phase, in which we infer the sense that particular actions make.

We analyse the actor's personal accounts of the situation with the aid of von Wright's principle of behavioural inference of reasons which is adapted into Peirce's meaning-relationship model (Peirce 1998a, von Wright 1998a). We identify the actors' understanding of the meanings of operations as reasons for action. With reference to models of the activity system and the intrinsic constraints of the domain we analyse operations and the accounts given to action and identify habits of action and orientations. These reveal the personal sense of action.

As a result of the inferences we acquire knowledge of what people really do in their work, i.e. what are the content and demands of their actions, how the actions are constructed in situations, and what could be considered as appropriate practices with regard to attaining the desired outcomes. The results of the analysis are depicted in the centre of the figure.

The inference scheme in Figure 19 comprises three parts, the formative modeling of the work domain, analysis of habits and the reason-based analysis of (courses of) actions. In the following we shall clarify the steps of inference and the criteria of evaluation of actions with the help of our study on the clinical practice of anaesthetists. Thereby we also elaborate the different forms of data acquisition. We shall also provide empirical results that should demonstrate the validity of the habit-theoretical perspective adopted in the method. In the chapter following this one (Chapter 7), we shall elaborate the method and the concept of habit of action with the help of a further example that deals with piloting of ships in restricted waters.

6.2 Formative modeling of anaesthesia activity

In the study of anaesthesia, our aim was to describe the objectives and intrinsic constraints of the work domain and the task situation, and to analyse the anaesthetist's habits of action. We intended to do this by analysing the anaesthetists' normal work. The study was accomplished as an interdisciplinary work together with an expert anaesthetist Ulla-Maija Klemola, who substantially contributed to the advancement of the core-task methodology during the study. The results of the study have been published in several papers, to which we shall refer for further information. In this presentation we shall concentrate on demonstrating the development and use of the Core-Task Analysis method during the study.

Most studies on anaesthesia practice take the information processing approach as their point of departure (Bogner 1994, Gaba & Lee 1990, Nyssen & De Keyser 1998). Even those authors who express an intention to distance themselves from the cognitivist vocabulary, appear to have difficulties to develop an alternative methodology (Bogner 1997, Manser & Wehner 2002). We worked within an ecological frame. Action in a human-environment system is conceived as intentional and directed, and the environment is seen to form a meaningful context for action. Therefore, we started the explanations of actions by questioning the anaesthetists about their activity (Eskola 1999, Harré & Gillet 1994). We conducted interviews for determining the actors' orientations to the object of their activity, and utilised their communications during the actual work performance for interpretation of their behaviour.

Our study of anaesthetists' practices comprised of three phases. In the first phase an interview study with 16 expert anaesthetists was accomplished (Klemola & Norros 1997, Norros & Klemola 1999). In the second phase, half of these experts participated in a further study, in which actual practices were investigated in real clinical situations (Klemola & Norros 2001, Norros & Klemola in press). The third study focused on young anaesthetists, the residents who participated in the specialist training. In a longitudinal study we investigated both the subjects' conceptions of their work and the formation of the professional clinical practices over a period of about 10 months (Klemola & Norros 2002).

In the following, we shall demonstrate the use of Core-Task Analysis for the study of the anaesthetists' practices. We shall proceed according to the Core-Task Analysis scheme that was sketched in the previous section. Thus, we first accomplish a formative modeling of anaesthesia as a work domain from an activity-system point of view. Then we shall demonstrate how anaesthesia activity may be modeled from a habitual perspective. Finally, we shall elaborate how we carried out the reason-based analysis of courses of action and how we inferred the existence of particular habits of action in the empirical material.

6.3 Analysis of the work domain

The background for the conceptualisation of the anaesthesia activity was the profound practical and theoretical acquaintance with the domain by the senior anaesthetist of the research group. We made use of different kinds documentary material, and conducted an interview with 16 expert anaesthetists. Each expert was queried about his or her practice in a semi-structured way in an intensive session. The questions were devised according to themes derived from the cultural-historical conception of activity. Regarding the object of activity, we questioned about the experts' definition of it, the patient in anaesthesia and the expert's conceptions of his/her possibilities to acquire knowledge of the patient's state during anaesthesia. The anaesthetists also had a chance to express their opinions about striking a balance between the contradictory functional demands on inducing, maintaining and controlling the anaesthesia process. Much attention was paid to the experts' conceptions of the nature of the monitor-based information and of the role of monitors in their work. We also posed questions concerning the use of anaesthetic drugs. With regard to the subject, questions about the determinants of expertise and ways of coping with the demands of the work were asked.

The extensive material was analysed utilising a grounded theory approach (Charmaz 1995). Thus, the data of each subject was first considered and coded. Frequently appearing codes were selected and the whole data was filtered through them. After several iterative cycles the most relevant conceptual categories for the definition of the activity emerged. The results may be expressed in the core-task scheme as follows.

Analysis of the anaesthesia activity system

The Core-Task Analysis scheme assumes comprehending the object activity. This indicates that a conception should be formed of the global objective or the target of the activity and of the societal motivation, with which the object is connected. The experts appeared to share the main objective of anaesthesia, which is to enable surgical treatment by ensuring a sufficiently deep sleep during all phases of surgery without endangering the safety of the patient. In generic terms, efficiency, safety and excellent quality of performance must be ensured in anaesthesia activity with regard to every particular anaesthesia. With the help of the model proposed by Engeström (1987), the conceptualisation of the object of anaesthesia may be enlarged to cover the whole activity system of anaesthesia. In the activity-system model of Figure 20 we have indicated the dominant developmental perspectives that could be outlined on the basis of our material.

There appeared to be a fundamental problem in the system with respect to the way to achieve the required outcome, i.e. efficiency, safety and excellent quality of the care. Regarding the object of activity, the patient in anaesthesia, we proposed the hypothesis that safe and efficient care of ageing and severely ill patients requires individually-tailored care because, due to the reduction of these patients' own potentials to withstand the effects of anaesthesia, the safety marginal in anaesthesia becomes narrower. A developmental strategy would therefore be required, according to which enhancement of the situative appropriateness and adaptability of the anaesthetists' actions to meet the particular requirements of the patient would be the leading goal.

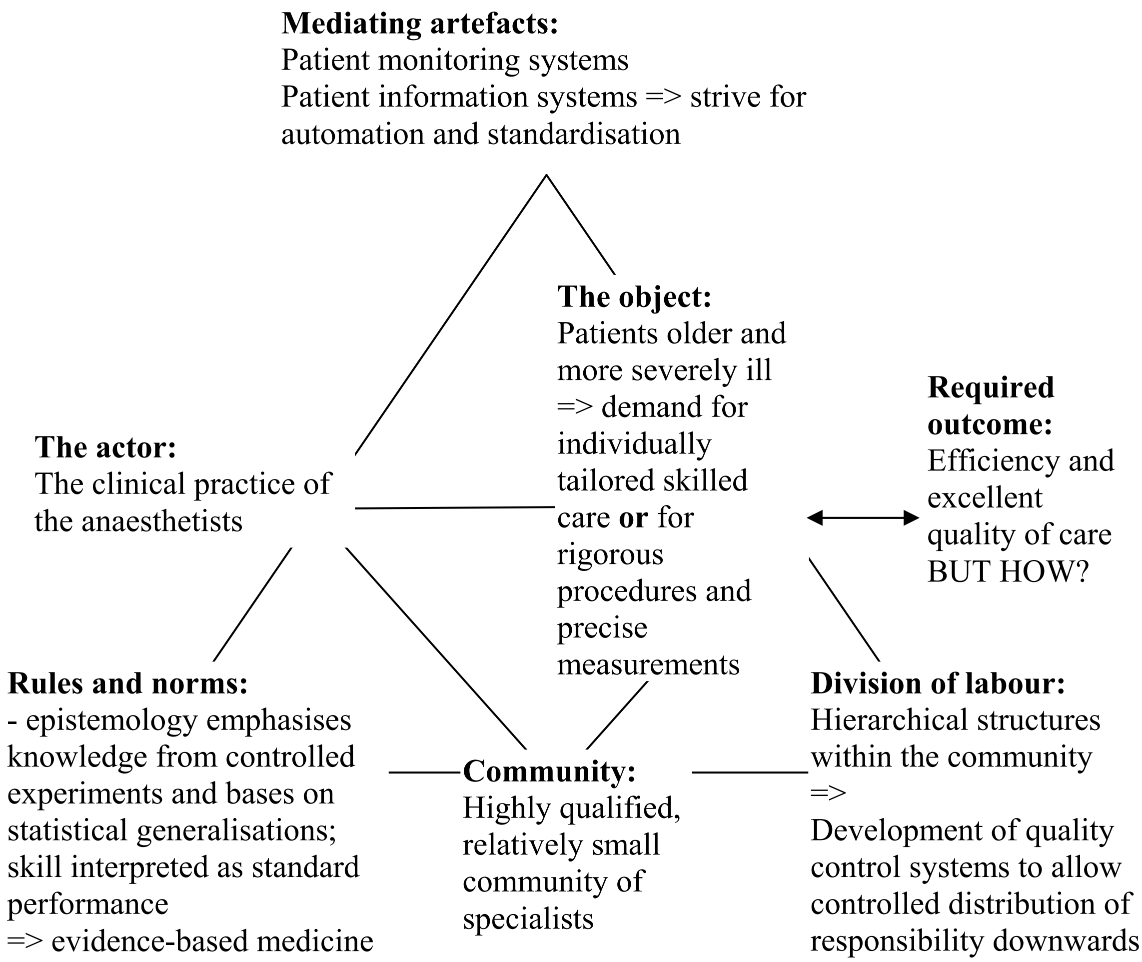

Figure 20. An activity system model of anaesthesia activity.

The current trends in developing the elements of the activity system appear, however, to foster another type of strategy, a standardisation-oriented strategy. There are reasonable arguments that support this alternative. Thus, e.g. the technical development of the patient monitoring devices is expected to be the major source of improvements in patient safety. The development of the devices is also driven by pressures from the competitive markets on the manufacturers to continuously introduce new developments of monitoring devices. As a result, new features are added to the monitors, the functional relevance of which for the practice is not necessarily evident (Salmenperä 2000). It is not uncommon that the poorly understood characteristics of the equipment remain under-utilised in daily practice (Klemola & Norros 2002). The prevailing epistemology of practice within medicine values highly rigorous measurable knowledge (Klemola & Norros 1997, Schön 1988). Hence, there exists great enthusiasm among practitioners about the possibilities of on-line measurements of physiological patient parameters. The theoretical restrictions that the new measurements entail seem to raise less caution than they would deserve, and the interpretative demands of the measurements do not draw the necessary attention (Salmenperä 2000). It has been suggested that the present philosophy in the design of monitors may develop a shallow understanding of the physiological phenomena and a way of working that orients to pre-given sets of rules (Vicente 2002). Furthermore, the pressure for efficiency in the post-operative phase of care motivates the development of monitors that allow effective simultaneous surveillance of the patients in the recovery room.

A further trend in implementing ICT in anaesthesia activity is the construction of patient information systems. Such systems have become necessary for managing the continuously increasing information concerning the patients in a controlled and reliable manner. The use of such large systems requires considerable attention and active operations. The relevance of the information that can be made available, and the appropriateness of allocating time to operating these systems with regard to the core tasks of anaesthesia, are open questions (Anceaux & Beuscart-Zéphir 2002).

We did not intend to claim that these and other technical developments in the artefacts are negative as such. Instead our aim was to formulate the hypothesis that the prevailing logic in the development of the anaesthesia activity-system appears to emphasise standardisation and technical means as the main strategy in the accomplishment of the reliability and efficiency of patient care. This strategy also appears dominant in other spheres of the activity system. There exists strong pressure to construct systems of rules and norms for attaining a rigorous regulation of the professional performances of the medical personnel. Correspondingly, improved prescriptions concerning the division of labour and allocation of tasks among the community are designed. Our concern is that the prevailing standardisation-oriented conception of development within the system might, perhaps, not be appropriate with reference to those demands of the task that, according to our analysis, are characterised by adaptation to the highly individual and non-predictable needs of the older and sicker patients. A recently published report of the development trends of the Finnish health system also supports our analysis in claiming increased patient-centredness in the development of the system (Alasaarela 2003).

One of our research aims, therefore, was to elaborate the strategic dilemma within the activity system and to analyse how it would manifest itself in the practices of the experts, and in the professional socialisation of the young anaesthetists in their residence time. We were also interested in developing views for an optional developmental strategy. This strategy should orient towards increasing adaptability of actions in the system through enhancement of professional expertise of the medical personnel. We also maintained that the exploitation of the possibilities of the ICT in the design of new medical appliances would necessitate an increase of the competencies of the personnel.

Outcome-critical functions of anaesthesia

The principle of the formative analysis of the work domain that we have adopted in the Core-Task Analysis assumes that the *critical functions of the domain* will be defined. We therefore conceptualised the constraints of the domain on a functional level utilising the modeling method explained in the preceding chapter. The modeling that we carried out has close resemblance with that reported by Hajdukiewicz et al. (1998 and 2001). However, in our modeling we considered not only the physiological phenomena but also their interactions with the constraints put by the different types of drugs and the surgical operations.

In anaesthesia the anaesthetist is dealing with the physiological processes of the patient, which are manipulated by potent anaesthetic agents and by the surgical operations.

According to our analysis the general objective of anaesthesia is to enable a surgical operation to be performed efficiently without endangering patient safety. In order to achieve this objective the anaesthetist must *strike balance between several critical demands regarding the patient's physiological functioning under the vital constraints set by the anaesthetic agents and the surgical stimuli*. These constraints also include *adequate control of complex non-linear drug interactions between the drugs effecting the level of consciousness, pain and muscle relaxation* (see details in Klemola & Norros 1997).

Another critical function relates to the *nature of knowledge of the patient's physiological reactions to anaesthesia*. Whereas there is an extensive and continuously expanding body of scientific knowledge concerning the physiological phenomena of the patient during anaesthesia, the validity of this knowledge, and, the physiological potentials of the particular patient are only imprecisely known before anaesthesia. A comprehension of the potentials must be inferred based on theories and statistical results of experiments regarding specific physiological phenomena in controlled settings. Therefore, the course of anaesthesia is basically unpredictable in any particular case.

There is the possibility to create new knowledge of these phenomena during the treatment of every particular patient. However, it is usually not necessary to take conscious advantage of this epistemic possibility, because normally the patients have a rather good potential to compensate the negative effects of anaesthesia. Therefore, generic knowledge of the physiological phenomena is sufficient for creating a broad enough safety marginal in the conduction of anaesthesia.

Finally, the process sets demands on the *mastery of pharmacokinetic and -dynamic necessities, in particular, the specific time constant governing the time courses of drugs, and thus, requires anticipation of actions.*

Analysis of anaesthesia process

We also modeled the work domain from the sequential point of view. Thus, the main *phases of anaesthesia* can be constructed when taking a task-related causal point of view to action. We distinguished three phases, the *preoperative evaluation, transformation of the patient's homeostatic state, and maintenance and regulation of the transformed state*. These phases do not simply state a sequential order of events. Rather, being related to the above-mentioned critical functions of anaesthesia, their role for maintaining the functions becomes overt. The phases were decomposed further in several elements or tasks that represent the actor's interactions with the object of activity. The sequential model was used later in the process-tracing analysis to describe the situated constraints of the task and to provide the elements for structuring of the criteria of habits of action (Klemola & Norros 2001, Norros & Klemola 1999).

In a professional activity it can normally be assumed that the agent takes into account, at least to a certain extent, the critical functions of the work domain. As a result of the above conceptualisation of the work domain we were able to formulate the following hypothesis regarding the demands on the situated actions of the anaesthetists: Due to poor level of knowledge of the physiological potentials of the patient before anaesthesia the anaesthetist will probably make use of the physiologically especially informative phases of the process, the anaesthetic induction, to make inferences of the patient's physiological potential. At the same time the anaesthetist makes use of the information for controlling the on-going process. Formation of a cumulative interpretation of the physiological potentials of the patient in the most informative phases of the process would provide a basis for regulating the state of the patient in later phases, during which unwanted physiological complications cannot be excluded (Norros & Klemola 1999).

6.4 Analysis of habits: defining indicators and criteria for habits of action

In order to test the hypothesis derived above we analysed our research material from the perspective of the actual situated action of the anaesthetists. The material of the above-mentioned interviews and the extensive observational studies of the anaesthetists' performances in clinical situations in operating theatres were used for this purpose. The clinical material comprised of registrations of 16 anaesthesia processes administered by 8 experts, who were randomly selected from the participants of the interview study. The experts selected the patients from the weekly operating list. The instruction was to prefer patients with physiological reserves that were limited at least to some degree. A wide range of observational material was collected. Besides video-recordings, the domain expert of the research team made documented observations of the patients' responses and the anaesthetists' actions. Special attention was devoted to their mutual, temporal relationships. Partly pre-structured process-tracing interviews were carried out. The first interview was accomplished pre-operatively, the second during the operation and the last and most extensive one immediately after the operation.

From our observations of the clinical situation we acquired a rich data of the courses of action of the anaesthetists. However, not even detailed reproductions of the courses of events of the behaviour can explain the meaning of the observed sequence of elements. Therefore another type of explanation is necessary, in which the meaning of the observed courses of action is inferred. The observations of the anaesthetists' actions were analysed from a semiotic point of view, with the aim, firstly, to infer the criteria for habits of action, and secondly, to define existing habits of action. The criteria of habits of action express the outcome-critical meaning of behaviour.

The *criteria for habits of action* are empirically determined through analysing the way in which situational information is utilised as a tool in an actual clinical action. In the definition of the criteria we could also make use of the results of the interviews concerning the anaesthetists' descriptions of their habits of action. In the formation of the criteria we refer to the second phase in the CTA, the analysis of habits (see Figure 19).

Analysis of habits on the basis of courses of action

The investigator may make assumptions of the possible sensible logics according to which the agents may be acting in a DCU-situation, such as anaesthesia, in which adaptability of action is required. According to the pragmatist conception, the subject's intentionality in relation to the environment may be understood as a habitual relationship. The mode of this relationship is seen to be abduction. As indicated in Chapter 3, Peirce considered abduction as a continuous transition between the states of doubt and belief, which qualifies the way habits work. Abduction manifests itself in a two-fold tendency in the human action. The actor is both attentive towards the specific features of the present situation, and simultaneously he/she strives towards a general interpretative relationship with the environment. The latter aspect is necessary for achieving continuity in the ever-changing environment. In his first Harvard lecture (Peirce 1998a), Peirce maintained that the strength of abductiveness of the human-environment relationship manifests an interpretative perception of the environment. Lack of interpretativeness denotes a relationship that Peirce calls reactive.

We draw from the theoretical position of Peirce and define the tendencies towards *interpretativeness and reactiveness* as constituents of a generic evaluation dimension for habits in our Core-Task Analysis. The notions of coherence and situativeness which we used as theoretically-based evaluation categories of operators' actions in our nuclear power plant studies (Dewey 1999, Hukki & Norros 1998, Ilyenkov 1977) were understood by us as generic tendencies of human action in uncertain environments. We may interpret this characterisation of the nature of action to have a close resemblance with the Peircean conception of an abductive relationship and with the interpretativeness-reactiveness dimension that may be derived from it. We utilise the Peircean dimension as the underlying evaluation dimension in our analysis of habits.

The generic habitual relationship toward the environment is concretised in the Core-Task Analysis scheme in two ways. First, we separate the observable courses of action, which are conceptualised as tool-using *human-environment interactions.* The abductive dynamic expresses itself in *adaptability* of action achieved by these interactions. This is the first concretisation of the underlying evaluation dimension that expresses an abductive relationship to the environment. In the case of anaesthesia the human-environment interactions are interactions between the doctor and the patient. Drugs, patient information and professional concepts were conceived as tools of the anaesthetist, with which he/she interacts with the patient with the aim of maintaining the patient's physiological state within safe boundaries. The anaesthetists' actions and the patients' physiological and other responses were recorded through observation and video-recordings. On the basis of this data we constructed graphical representations of the action-perception cycles. An example of such representation is depicted in Figure 21.

Figure 21 depicts a timeline of the induction phase of anaesthesia of one patient. Different kinds of operations, such as giving drugs, laryngoscopy, auscultation, communicating with the patient, etc. are indicated as upward arrows. The downward arrows above the timeline indicate perceptions of information, monitored parameter information, direct reactions of the patient, the clock. The parameters are indicated in the left. We were especially interested to identify what kind of action perception patterns appeared in different cases and what reasons the actors gave to explain their operations. Clearly identifiable performance patterns could be observed in the courses of action of different practitioners.

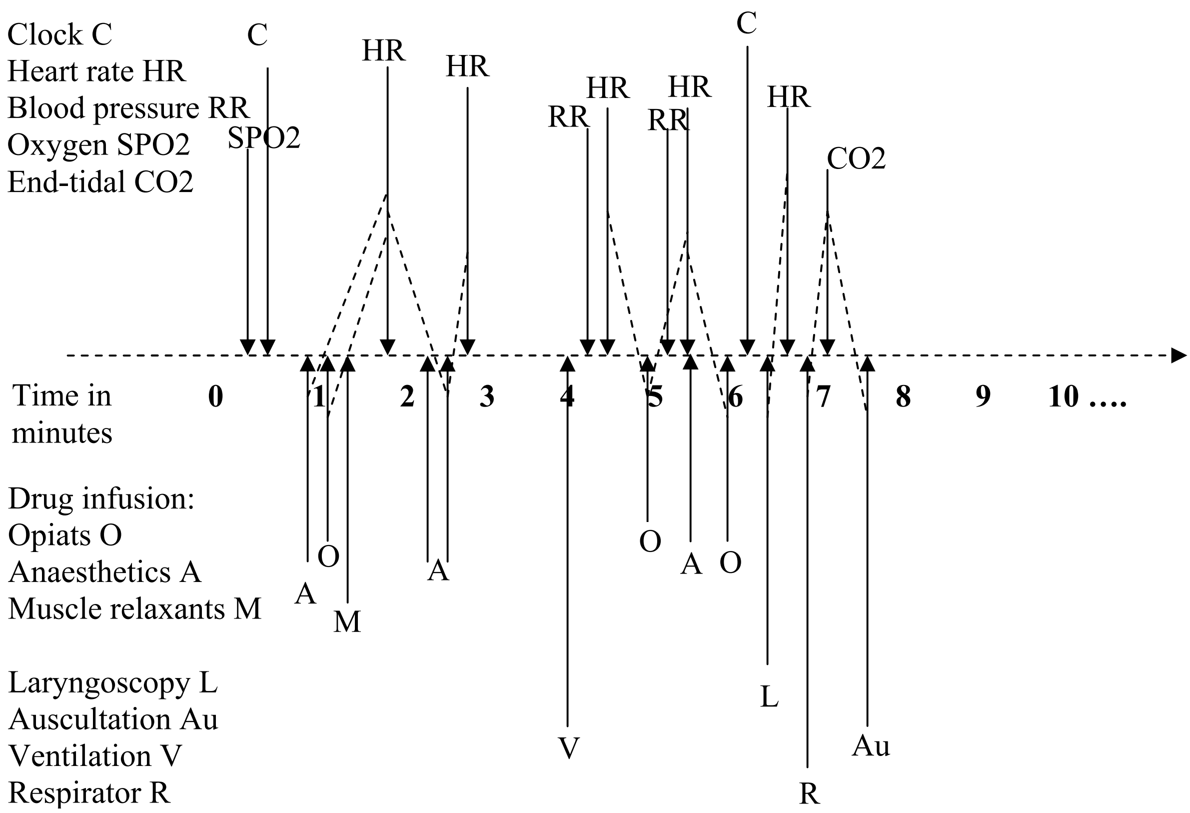

Figure 21. An example of a timeline from anaesthesia induction constructed on the basis of material from videotape, expert observations and process tracing interviews. Below the time line we indicate the operations and above perceptions of the anaesthetist. Our analysis was focused on searching perception action-perception cycles that are depicted by dashed lines.

Connecting operations to the core-task demands

According to the Core-Task Analysis scheme, the concretisation of the generic abductive relationship with the environment should also be accomplished from a functional, outcome-critical perspective. This perspective opens the possibility to relate operations to the *core-task demands* of activity. *Core-task orientedness* is the second concretisation of the underlying evaluation dimension that the abductive relationship to the environment is thought to express. It forms an evaluation dimension that refers to the contextual coherence of actions.

As was indicated above, the conceptualisation of the activity of the anaesthetists resulted in a hypothesis concerning a central task of the anaesthetist. We claimed that due to the poor knowledge of the physiological potentials of the patient before anaesthesia, the anaesthetist takes advantage of the physiologically especially informative phase, the anaesthetic induction, to make inferences of the patient's potential while at the same time controlling the process.

This hypothesis reflects the investigators' assumptions of the possible sensible logics of the agents in their taking into account the result critical functions of the particular work (modeled in CTA phase: analysis work domain). From this hypothesis we thus derived the following four *core-task demands* (see the inference scheme in Figure 19). In our earlier model of diagnostic judgement in a disturbance situation (Hukki & Norros 1993) we distinguished the diagnostic and operative aspects of judgement. This distinction is also valid in the normal situation. The first two core task demands refer to the diagnostic and the two other to the operative aspects of diagnostic judgement in a normal process control situation:

- rich use of *situated* information
- cumulative *interpretation* of the physiology of the patient
- *anticipation* of the dynamics of the process in the control of anaesthesia
- *preparedness* and checking attitude in the use of tools.

The core-task demands are functional requirements that manifest themselves in specific forms in particular situations and set constraints and possibilities for the tool-using interactions. In the analysis of the courses of actions (left-hand side of the CTA scheme, and Figure 21 above) the interactions are related to the constraints and possibilities of the situation. The interactions are characterised according to how the core-task demands are considered.

The actor himself is not claimed to *aim* at fulfilling the core task-demands. Instead, the actors are concerned of the outcome-critical functions of the work. The defined core-task demands serve the external analyst, who makes inferences about the actors' behaviour. Firstly, the analyst defines the central phases of the task. Whithin them the investigator finds behavioural elements that may be interpreted with regard to the core-task demands. Thus, concrete behaviours, or operations, of the actor are defined that manifest core-task demands, i.e. are core-task oriented. These operations, that constitute indicators of habits of action, are then graded according to the interpretativeness-reactiveness dimension. As a result the *adaptability* and the *core-task orientedness* dimensions are merged in the emerging criteria of habits of action. If an operation in a concrete situation can be defined as fulfilling the core-task demand in an adaptive way, we then interpret that the actor has taken into account the outcome critical functions of the task. As a result a certain feature of practice is identified.

Working in the above-described way we went through our behavioural data of the anasthetists' actions in the operating theatres several times. As a result we acquired a first set of criteria for habit of action (Klemola & Norros 2001). The referred paper provides the contextual grounds for each criterion. In it, examples of behaviours that were interpreted to express a certain criterion are presented. The criteria are summarised in the following Table 15.

Table 15. Functional phases of the anaesthesia process (bold), indicators (italics) and criteria for evaluation of the anaesthetists' habits of acting. The asterisks denote the criteria (Klemola & Norros 2001, p. 458).

Preoperative evaluation of the patient

Evaluation of physiological condition regarding anaesthesia
* Mere enumeration of concurrent diseases
* Attempts to evaluate the severity of concurrent diseases
* Interpretation of the patient's physiological potential regarding anaesthesia

Patients physiological condition as a constraint on the anaesthetist's activity
* No constraints
* Constraints according to common, classifications and general rules
* Emphasis on situational information as grounds for guiding administration of anaesthetics

Transformation of the patient's homeostatic state by inducing anaesthesia

Interplay between administration of anaesthetic drugs and available information
* Anaesthetics were given on a weight basis, or according to a predetermined scheme
* The patient's sleeping dose was determined only by following the level of consciousness
* Besides consciousness, information from the patient's physiological responses was chosen as grounds for dosing drugs for anaesthesia

Use of information from cardiovascular intubation response
* Information was not used
* Deliberate search for information

Evaluation of the patient's physiological condition after the transformation phase
* Pre-formed conception was confirmed
* Cumulative interpretation of the patient's physiological potential was constructed on the basis of his responses during the transformation phase

Maintenance and regulation of the transformed homeostatic state

Maintenance of balance between adequate depth of anaesthesia and optimal physiological state
* Cardiovascular depression was minimized at the cost of anaesthetic depth
* Balance was maintained with appropriate means

Maintenance of balance between cardiovascular stability and surgical stimulation
* Reactive approach to maintaining balance
* Anticipatory approach to maintaining balance

Regulation of the transformed homeostatic state by using tools
A. Use of information
* Controversial reactions to information
* Regulation was based on information trends and/or on a predetermined scheme
* Regulation was based on internal tempo of the process in accordance with previous patient responses, and situational demands

B. Adjustment of anaesthetic drugs
* Contradiction between drugs given and theoretical knowledge referred to by the practitioner
* Anaesthetic drugs were adjusted with a mean accuracy, or their advantages were not exploited
* Anaesthetic drugs were adjusted in accordance with the history of the process, and through anticipation of future situational demands

The criteria are the result of the described conceptualising of the anaesthesia process in three phases, preoperative evaluation, transformation of the patient's homeostatic state, and maintenance and regulation of the transformed state. This conceptualisation of the anaesthesia process (resulting from the CTA phase: Analysis of the work domain) was used to form the phases in the habits of action criteria –frame. These are indicated by bold text in Table 15. The three phases were decomposed further into tasks that were identified as functionally significant in the analysis of the work domain. These are indicators of habits of action and are printed italics in Table 15. The distinct ways of performing the task are illustrated by the concrete items and indicated by asterisks in Table 15. These items, the habit of action criteria, are consistent with one of the two core task demands of anaesthesia, which we used in this study. These demands were the extent to which situational information was used to regulate the process, and the extent to which the anaesthetist created a cumulative interpretation of a patient's physiological potential [8]. The criteria that are presented in the table under each evaluation element express different levels of interpretativeness of action in increasing order (position in the interpretativeness-reactiveness dimension).

6.5 Reason-based analysis of actions of the anaesthetists

In the final phase of analysis of actions we use the described criteria of habits of action for inferring the existence of particular habits of action in the material. This is the third part of the CTA, which provides the actors' point of view to action. In Figure 19 the reason-based analysis of actions is depicted in the centre of the figure. The semiotic meaning-relationship model provides the conceptual basis for accomplishing the analysis. With the help of the derived criteria we make interpretations concerning the meaning of the actions to particular subjects, the personal sense of actions. The behavioural expressions of personal sense, habits of action, are combined with the conceptual expressions of personal sense, which are acquired by inquiring the subjects' orientations. With the help of this information we may draw conclusions about the content of actions and explain the construction of the courses of action. The first part of the CTA, the formative modeling of the situation, enables the evaluation of actions according to internal criteria of appropriateness in the particular task.

Analysis of orientations

The interview material collected in the study was analysed from the point of view of orientation; i.e. we defined what personal sense the anaesthesia work makes to the subject. This was clarified through defining an actor's stance to the object of activity, the patient. Orientation was conceptualised through a few central dimensions that were derived from the material. The first dimension was the conception of the anaesthesia process: either recognising uncertainty or not. The second dimension was the attitude of the doctor towards the patient: either communicative or authoritative. When the material of each interviewee was subsequently classified on the basis of these criteria, we could obtain two basic orientations. The first one was the "realistic" orientation, which was qualified by the recognition of the patient's uniqueness and the

[8] A more comprehensive set of criteria was developed in the next phase of the study. In this latter version of the criteria we took account of all the above-defined four psychological core task demands.

uncertainty of the anaesthesia process. The other basic orientation was the "objectivistic" orientation, which was qualified through the treating of the patient as a natural object to be controlled. This conception was connected with a conception of anaesthesia that did not include deliberate recognition of uncertainty in the process.

Analysis of habits of action

The analysis of orientations that we described above and the results that we obtained express the personal sense of action. Our next task was to develop a way to become knowledgeable of the personal sense embodied in the operations. The task is to infer the logic according to which the actor takes into account the outcome-critical functional demands of the domain as reason for his action, i.e. what are his habits of action. The theoretical basis for the inference of the habits of action is the principle of behavioural inference of reasons suggested by von Wright (1998a). The author elaborates the principle of behavioural inference of reasons with an example of a person's behaviour when hearing a knock on the door. Von Wright writes:

> "That persons understand the meaning of knocks as a reason for opening doors means that in normal cases they react to knocks in the adequate way unless they have overruling reasons against the action. This is a conceptual observation and it provides us with criteria for identifying, testing, verifying that or whether a person has (acquired) the understanding in question. It gives us the phenomenon of understanding." (von Wright 1998a).

This principle means that if we can identify understanding such meaning relations as reasons for action we can assume that people normally act accordingly. This idea has a close relationship with the pragmatist idea of habit as a meaning that the agent therefore repeats.

We have interpreted von Wright's example with Peirce's triadic meaning relationship (see Chapter 3) as follows (Figure 22).

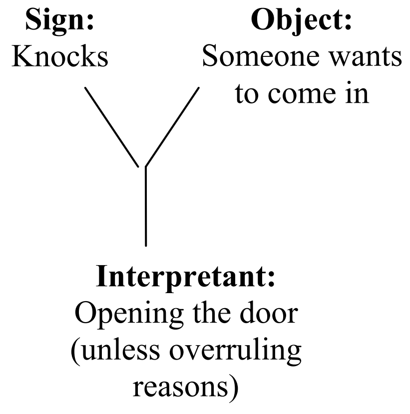

Figure 22. Peirce's triadic meaning relationship model.

The attempt was, then, to identify such meaning relationships through observing subject's operations (Interpretants) in relation to some significant signs in the situation (Signs) and defining respective reasons for action (Object).

In his principle of behavioural inference of reasons von Wright distinguishes between possible and efficacious reasons (von Wright 1998a). The former, the possible reasons are such reasons that may be identified as meaningful and reasonable in an environment by someone who is acquainted with the context. Defining of possible reasons relates to the formative modeling that we carry out regarding the situation. The efficacious reasons are reasons that are actualised in a particular person's actions. These are the reasons that we may identify in our empirical material, and which we use to analyse particular persons' actions in our reason-based analysis of action. A comparison between possible and actual efficacious reasons enables an evaluation of behaviour, as von Wright notes.

In the analysis of habits we derived optional meaning relationships that the persons have understood as reasons for action. These relationships were interpreted as possible reasons to act. They were evaluated with respect to how well they fulfil the demands on adaptive action in this work domain. These optional meaning relationships were collected as criteria for habits of action, as shown previously. In defining the actually effective reasons we rely on the subjects' explanations of their actions. In order to become knowledgeable of them it is necessary to carry out process tracing interviews, as we did.

We use von Wright's principle for justifying claims that a particular behaviour of a person has the character of a habit. We do not base our arguments of the existence of habits on observing a particular behaviour to appear repeatedly. Behaviours are in Peirce's terms merely energetic interpretants of signs if it cannot be shown that persons have understood the meaning of the sign as a reason to act. Von Wright's principle provides a way to become aware of the existence of such understanding.

The explaining of actions based on their reasons has significance for the analysis of changes in actions and learning. It may be claimed that a change takes place if the actor becomes aware of the object of action, i.e. if he sees what action denotes in a situation. Awareness merely of the interpretant, the actual behaviour, is not sufficient for the insight that might lead to change. Wygotsky also emphasised the importance of understanding the meaning of actions for learning. He saw that signs are tools of change through providing new meaning relationships (Koski-Jännes 1999, Vygotsky 1978). We suggest a connection between the cultural-historical and pragmatist notions of meaningful acts. The notion of operation in the cultural-historical theory of activity may be expressed within the meaning relationship model of Peirce (Project 1998, p. XXVII). The model would take the form expressed in Figure 23.

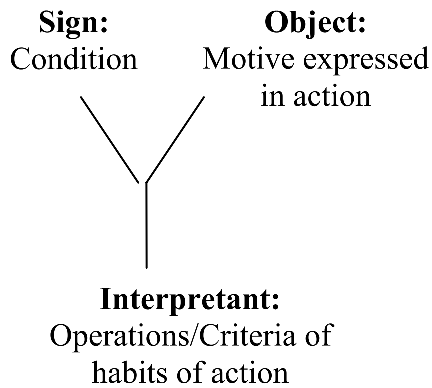

Figure 23. The meaning relationship "habit" as it is used to identify whether a person expresses a particular habit of action.

This interpretation of the meaning relationship model allows us to state that as we identify habits of action with the help of this model, we actually define societally determined meaningful practices.

We elaborate the way we use the reason-based analysis of von Wright in the frame of the Peircean meaning-relationship model in our empirical analysis of situated actions. One of the elements of evaluation that we constructed (Table 15) may serve as an example of the inferential logic used in the evaluations. We shall use the third indicator in Table 15. In the original version of the frame, this indicator included only three criteria. In this example we provide a more comprehensive version of this element, which includes four criteria of habits of action (Figure 24).

The example demonstrates four different habitual relations that the expert anaesthetists of the study manifested during the induction phases of anaesthesia, in connection with the task of inducing doses of anaesthetic drugs (Figure 24). The different bases of inference for different operations that are connected to particular situatively available signs are interpreted to denote the different possible senses that the situation may make to the professionals. One of them may be the actual efficacious reason for a particular person to act in the situation. The relations represented in the model express the different personal sense that the particular sign may make to the doctor with regard to the patient. Our example presents an item that expresses the fulfilment of the core- task demand of creating a cumulative interpretation of the patient's physiology. The relation S-I1-O1 manifests the weakest and the S-I4-O4 the strongest tendency towards this core-task demand and towards the underlying interpretativeness of action. The fulfilment of this demand is connected with the subject's understanding of the critical functions of the task. This connection is realised through the contextual criteria of habits of action. Thus, through being connected to the core-task demands the item informs us about the features of habits of action. Because the features of habit of action relate to the critical functions of the domain we gain understanding of how the critical functions of the domain are taken into account.

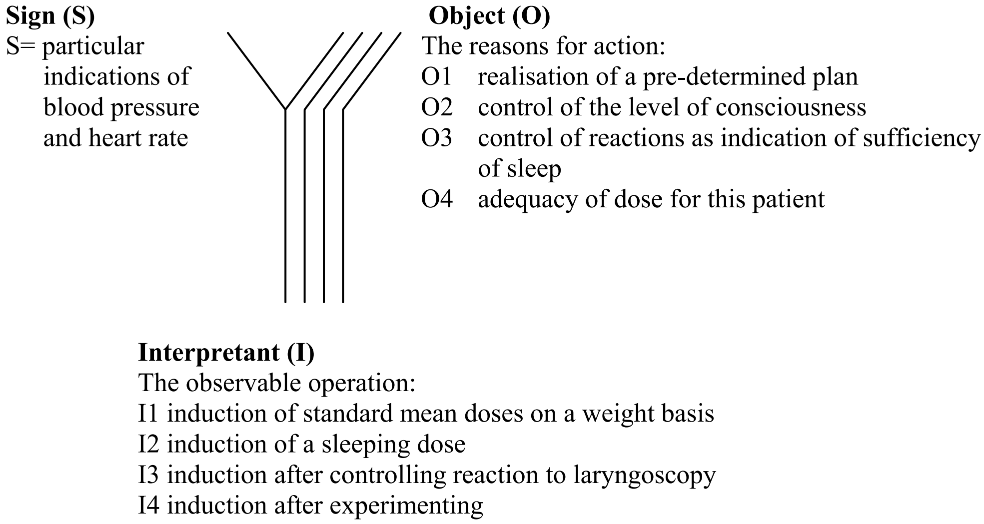

Figure 24. Demonstration of the inference of the meaning of particular operations during anaesthetic induction (Interpretants I1, I2, I3, I4) and their reasons (Objects O1, O2, O3 and O4) as reactions to the signs of blood pressure and heart rate (S).

The habit of action criteria provide a possibility to identify professional practices from the point of view of their meaning. As such the analysis may considered a cultural analysis of performance. The criteria were used to form profiles of each anaesthetist's habits of action. The criteria offered a mirror for the subjects to reflect on their practice. It became evident in the study that in an interview hardly any expert would report behaviours belonging to the first level criteria under each item. However, our results indicated that such practices are not rare.

In the final phases of analysis we studied the relationship between the orientation and the habits of action and formed profiles of professional practice, which we assumed to explain the differences found in the situated courses of action.

6.6 Summary of the results of expert anaesthetists' habits of action

As a result of our analysis of the clinical practices of expert anaesthetists we were able to define the essential content of anaesthesia activity in normal daily work.

The results enable identification of systematic differences in habits of action among expert anaesthetists (Klemola & Norros 1997, Norros & Klemola 1999, Klemola & Norros 2001). The central differentiating feature is the fulfilment of the psychological core-task demand of construction of a cumulative interpretation of the physiological state of the patient. The habit of action that fulfilled this demand was labelled *interpretative*. The characterisation refers to the assumed underlying interpretative tendency towards the environment that a full-fledged abductive-reflective habit manifests. The interpretative habit of action was characterised through deliberate construction of a personal cumulative interpretation of the physiological potentials of the patient. This interpretation also served as a reference for regulating actions in later phases of anaesthesia. This habit of action was also characterised through rich use of available information from several sources. The success of anaesthesia was controlled by multiple checks. The other major habit of action was named *reactive*. This label is also drawn from the habit-theoretical evaluation basis and indicates operating on a level of stating relations between observed phenomena without the abductive-reflective intention. Instead, the anaesthesia process is controlled with the help of predefined schemes, which way of working correlates with less intensive search for information. The reactive way of using information was characterised as confirming the execution of a pre-planned scheme, and the course of anaesthesia was anticipated according to common classifications based on types of patients, diseases or surgical interventions. The success of anaesthesia was controlled by maintaining pre-determined numerical values of parameters, for example, "maintaining a neat curve".

These major differences in habits of action correlate with the anaesthetists' conceptions of the object of activity, the patient in anaesthesia. The conceptions were obtained through the orientation interviews. The general tendency is that an identification of the existence of uncertainty regarding the reactions of the patient during anaesthesia, which was defined as a sign of a *realistic orientation*, relates to the interpretative habits of action in clinical situations. Because uncertainty is seen to be a consequence of the uniqueness of each individual and of the anaesthesia process, it is not surprising that it makes sense to set oneself in a communicative relationship with the unconscious patient through an intensive use of the available signs of the physiological reactions. Correspondingly, failures of identifying uncertainty, linked with a control-oriented relationship to the patient, were defined as qualifications of the *objectivistic* orientation. With this epistemic attitude, it does not make much sense to the anaesthetist to create knowledge of the particular patient. As a consequence a reactive habit of action emerges.

About one third of the expert practitioners studied in this work had adopted a realistic orientation and an interpretative habit of action. Among these practitioners reflectiveness in action does not seem to be triggered only by especially demanding events or situations, but instead it is maintained as a general habitual way of acting, which prepares the practitioner for possible difficult events. An important observation was that some practitioners who manifested the other major type of practice, the objectivistic orientation combined with the reactive habits of action, also had difficulties in the interpretation of information that clearly indicated safety critical levels of the vital physiological functions of the patient. Such unexpected deficiency of any expert's action may be explained through the nature of practices that these persons manifested. When a personal interpretation of the patient's physiological potentials was not available, there was no significant reference for the interpretation of alarming information. We may conclude that neither the reactive nor the interpretative habit of action is directly determined by the constraints of the situation. However, modulated by these habits actual situated courses of actions are more or less situatively appropriate.

6.7 Habits of action and the development of expertise among young anaesthetists

Formulating a hypothesis concerning the development of practices

In an earlier work (Norros 1995) we formulated a hypothesis that differences in orientation and habits of action would probably be relevant for explaining the development of expertise in work. We also assumed that such habitual differences in action are not a linear result of the amount of experience of different work situations. On the basis of our habitual conception of action we could propose the hypothesis that the construction of expertise must be co-determined by the significance that experience has for the actor. The comparisons between experts and novices, which are typically made on the basis of analysis of actual features of actions, are not sufficient for understanding the development of expertise in work. The Core-Task Analysis method, with which we may differentiate between the habitual potential and the actual course of action, should offer better possibilities to identify the logic of the construction of expertise.

As was explained in the previous section, we found differences between experts in their habits of action and orientation. The interpretative habit of action was conceived to reflect the underlying abductive dynamic. Typical to this is that attention to the specific phenomena of the object is connected with a striving towards generic interpretation of the phenomena to enable continuity in action. In our material concerning the experts' actions we could observe practices that were characterised by an experimental determination of the adequacy of doses of drugs and explicit interpretations of the patients' physiological potentials. These interpretations could be used as references in the regulating of the state of the patient in the later phases of anaesthesia. When we questioned the anaesthetists about their conceptions of the object of activity, we also found that this particular practice was connected with an epistemic attitude, which was qualified by the acknowledgement of the uniqueness of the patient. For this reason, idiosyncratic physiological reactions of the patient were carefully observed and interpreted for maintaining proper control of the process.

There is a striking similarity between our distinction between the interpretative and reactive habits of action and the two principle ways of relating oneself towards the world that John Dewey described (Klemola & Norros 2001, Norros & Klemola 1999). Dewey distinguished between an empirical-routine relationship that he called the primary experience, and the experimental-reflective relationship that was named the secondary experience (Dewey 1997, Miettinen 2000). In his model of experimental learning Dewey demonstrated how the latter relationship results in creation of new solutions to problems in action and facilitates learning. This model provides a theoretical explanation for our observation that the realistic orientation combined with the interpretative habit of action enables learning from the patient for the control of his/her physiological state within the on-going anaesthesia process. This theory suggests, furthermore, that the realistic orientation and the interpretative habit of action would also facilitate the development of the practitioner's own clinical procedures and practices as they are used and tested from one patient's anaesthesia to the next. The interpretative habit of action would thus be an essential factor in explaining the development of the expertise of the anaesthetists.

Longitudinal analysis of the development clinical practices

The third phase of our anaesthesia study was a longitudinal analysis of the development of young resident anaesthetists' clinical practices.[9] In this study we sought answers to two major questions. First, we should clarify whether there are differences in the orientations and habits of action among the young anaesthetists, which could be interpreted to correspond with the differences found among the experts. If the above assumption is verified, it should further be tested whether the observed differences are related to the efficiency of learning. However, the above reasoning should not be interpreted in a mechanistic way. Thus, the idea is not that habit of action, as a measurable entity would have an effect on expertise that could be measurable in an independent way. Instead, as we proposed already in the FMS study, we interpret habit of action and orientation to express an inherent potential of action that facilitates learning. Development of expertise should be understood as the formation of different kinds of expertise.

The development of professional orientation and the formation of habits of action take place in a community of practice (Lave & Wenger 1991, Wenger 1998). Therefore, particularly, in the early phases the professional socialisation, orientation and the habits of action are not very stabilised but rather they are prone to changes. Ingold (2001) emphasised imitation combined with improvisation as the major mechanism in transferring skill and knowledge. In reference to this observation, we may assume that the prevailing practices of the community of anaesthetists, in which the novices participate, shape the emerging personal practices of the novices.

For understanding the construction of expertise we therefore planned a study in which we observed the process of formation of the habits of action among the young residents during a 10-month follow-up time. All the 9 subjects of the study had about one year of experience as anaesthetists. In this time they had developed an initial personal approach to anaesthesia. They had acquired competencies that are necessary for acting independently in the operating theatre. The results of the study are reported, or will be reported in detail elsewhere (Klemola & Norros 2002, Klemola & Norros in preparation, Norros & Klemola 2001, Norros & Klemola in preparation). In this context we shall elaborate the methodical developments we made in the Core-Task Analysis method. We shall summarise the results that are needed to answer the theoretically important question about the connection between the habits of action and the development of expertise.

The analysis of the activity of the young anaesthetists was realised within the core-task analysis framework. The empirical methods of this study were basically the same as those used in the study of the experts. We conducted orientation interviews with each participant in the beginning and at the end of the 10-month follow-up period. The actions of anaesthetists were observed, and carefully recorded, in three clinical situations. We made important adaptations to the inference method and added new features in all phases of the CTA scheme, in the modeling of the work domain, in the analysis of habits, and in the reason-based analysis of actions.

[9] This study was also carried out by U.-M. Klemola & L. Norros. As all the results of this study have not yet been published we must in the following refer partly to work under preparation.

Modeling of the work domain

In the modeling of the work domain we used the conceptualisations of the object and activity system, which were established in the previous study with experts. The conceptions of the critical functions were considered to be sufficient on a general level. However, some specifications where made in connection with modeling the monitor information (see below). We also accomplished some elaboration with regard to the sequential modeling of the anaesthesia task. The decomposition of the anaesthesia process into the three major phases was found to be adequate. However, we wanted to extend the analysis with regard to the tools available for carrying out the tasks within these phases. The motivation to improve the analysis of the available tools is that empirical analysis of habits of action is based on observing the way in which the subjects make use of tools in interacting with the patient. The central tool for the anaesthetist is the monitor information that provides on-line measurements of the physiological functions of the patient.

Monitor information. We accomplished an extensive modeling action in order to conceptualise the normally available monitor information according to its information content and its functional informativeness (Klemola & Norros 2002). The modeling frame that we used resembles our earlier analysis of critical information within the functional constraint-oriented modeling approach that was explained in the previous chapter. In this case, however, the information afforded by the monitors was analysed without reference to any particular decision-making situation. The resulting model was called the functional information model.

The analysis of information was focused on all information items that are displayed on a standard multiparameter monitor used by the anaesthetists in their everyday work. The monitor consists of distinct parameter modules, such as respiratory gas concentrations, pulse oximeter, electrocardiograph, non-invasive and invasive blood pressure, etc. All modules and the displayed items within them were listed. These items were analysed and classified in the model with regard to their functional relevance.

Thus, three classificatory categories were constructed; the informational content of the presented items was considered to be associated either with physiological phenomena, phenomena belonging to the technical execution of anaesthesia, or ensuring the reliability of other displayed signs. Judgement of reliability was enabled by the supplementary safety back-ups offered by the device. They consisted mainly of simultaneous analog and digital displays of a parameter or crosschecking possibilities between distinct parameters. Further, within the first two categories the clinically most common phenomena about which the technically generated signs might yield knowledge were included in the table. Similarly, within the third category, the safety back-ups and crosschecking possibilities were tabulated. The classification principle of the functional information model is presented in Table 16.

Table 16. An extract of the functional information model. It demonstrates the structure of the model that includes information that is monitored on the standard multiparameter patient monitors. The example elaborates the analysis of the information about the carbon dioxide in the exhalation phase (end-tide).

Monitor Inform-ation	**Information content**			**Relevance to anaesthetic practice 1=essential 2=imp. 3=less imp.**			**Cons-traints**
% rated essential	Phys. Phenom-ena 41	Techn. execution of actions 61	Relia-bility of infor-mation 35	Vital safety 54	Interp. Physiol. Functions	Control of own action	
EtCO2	CO2 concen-tration in end-tide						
	Hypo/ hyper ventila-tion				1		
	On-line CO2				1		
	On-line CO2:catas trophe			1	1		
	Meta-bolism			1			
		Position of intuba-tion tube		1		1	
Upper limit alarm							Is the alarm set on: limits and tone
…							
Σ 120 items	220 items						89

Thereafter, the significance of each tabulated item (of a total of 220) was evaluated n terms of the main functional demands of the anaesthetic practice. The demands were securing vital patient safety, interpretation of physiological functions, and control of the anaesthetists' own performance or the adequate functioning of technical devices. Subsequently, within each category the items were ranked using a scale: essential, important, less important. Of all items, 54% were judged to be of essential importance. The alarm function as a whole was considered to be the most important asset for patient safety and it was evaluated separately.

The technical design has basic assumptions that create constraints on the measuring instruments that the anaesthetist needs to take into account in practice for verifying the proper functioning of the communication channel for transmission of information required for constructing knowledge of the phenomena. With regard to each parameter we also listed the most basic constraints that affected the functioning of the information channel (in total 89) (Klemola & Norros 2002).

The above-described model was utilised when we queried the young anaesthetists' mastery of the functionally relevant information of the monitors as part of the orientation interviews conducted at the beginning and the end of the follow-up period. The information model was also utilised in the analysis of the participants' clinical actions and in inference of the habits of action.

The anaesthesia agents are, of course, another central tool in conducting anaesthesia. In this study we did not have a possibility to model the features of the drugs in detail. However, we analysed the most central characteristics of drugs in the context of elaborating the content of the conceptual knowledge from the point of view of practical conducting of anaesthesia.

Professional knowledge may be conceived as the third central tool to which we paid attention in this study. When collecting the investigation material concerning actions in the operating theatres, it became evident that there were wide variations in the young anaesthetists' personal knowledge guiding their judgements and interpretations. We decided to probe this question systematically and therefore created a model of the functionally relevant theoretical knowledge. This form of knowledge was called *actionable knowledge* and it refers to formal theoretical knowledge that is transformed into conceptual tools relevant for coping with problems commonly present in practice (Klemola & Norros 2002).

The participants' conceptual knowledge about the themes selected for the discussions and the model were systematically inquired and insufficiencies were amended. During the following sessions we checked the extent and the way in which the participants had adopted the offered knowledge. The areas of knowledge were: definitions of anaesthesia and the depth of anaesthesia, synergistic interaction between hypnotics and opioids, MAC-concept vs. monitor MAC-value and appropriate concentrations of inhalational agents[10] and principles of pharmacokinetic and dynamic theory (see details in Klemola & Norros 2002).

Analysis of habits

We also made some elaborations of the method with regard to *the analysis of habits*, the second part of the core-task scheme. It is commonplace in studies of expertise that the actions of novices and experts are measured with the help of a standard method that focuses on the description of the actual courses of actions (Chi et al. 1988, Dreyfus & Dreyfus 1985). Such a procedure may be argued as a necessary prerequisite for making valid comparisons between these groups. As a result, typical differences in behaviour may be observed. Such a context-independent measurement

[10] The acronym MAC stands for Mean Alveolar Concentration. It refers to the minimum alveolar concentration of an inhaled anaesthetic required to prevent 50 percent of subjects from responding with purposeful movement to a painful stimulus, such as the initial surgical skin incision.

of action, however, neglects the fact that the professional situation of the two groups of practitioners is completely different (Sandberg 2000). Therefore the achieved result may be expected to reflect the differences in the professional situation. It is not very sensitive in revealing characteristics of the habitual practices of these two groups. The latter differences were assumed by us to be significant indicators of expertise.

Specific to the professional situation of the novices is that it constitutes an explicit learning phase. The activity is therefore characterised through still restricted familiarity with the available theoretical and practical tools of the profession. Our method for the analysis of action uses a vocabulary that, based on the observation of actions in actual situations, allows comprehension of the potential habitual level of action. Through the analysis of habits of action we identify features that express developmental potential.

In order to take adequately into account the particularities of the professional situation of the young anaesthetists, we made some modifications in the method that we had used previously for the inference of the criteria for the habits of action. In the previous version we used only the two diagnostically oriented psychological core task demands as functional interpretants of the perception-action cycles for drawing the criteria for habit of action. These two psychological core-task demands were the rich use of situated information, and cumulative interpretation of the physiology of the patient. In this case two further, operationally related demands, i.e. anticipation of the dynamics of the process in the control of anaesthesia and preparedness and checking attitude in the use of tools, were used. In the final evaluation there were 19 task-related elements of evaluation, that were ordered in the three earlier conceptualised functional phases of anaesthesia, namely preoperative evaluation of the patient, transformation of the patient's homeostatic state by inducing anaesthesia, and maintenance and regulation of the transformed homeostatic state. Two elements were ordered under a fourth section that focused on the role of monitoring devices in practice. Of course, the underlying evaluation dimension interpretative-reactive that was drawn from the theory concerning the abductive dynamics of habit was used. The detailed description of the evaluation criteria for habit of action of the young anaesthetists is provided in an article under preparation (Norros & Klemola in preparation).

Reason-based analysis of actions

As in the previous study with the experts, we conducted orientation interviews to reveal the basic epistemic relationship of the agents towards the object of activity. As indicated in our theoretical model, orientation is assumed to express personal sense of the work for the actor. An orientation interview was carried out in the beginning and in the end of the follow-up period. For the determination of the anaesthetists' orientation we used three elements; comprehension of the particularity of the patient, identification of the uncertainty in the anaesthesia process, and comprehension of the mediated nature of monitor information in representing the physiological homeostasis. The last element that reflects the anaesthetists' conceptions of the epistemic nature of their central tools was not deliberately included in the definition of orientation in the expert version. Because the significance of these conceptions for action was identified in the study of the experts this aspect was included in the definition of orientation of the novices. This feature was expected to be informative in explaining the way in which the novices comprehended and utilised monitor information.

The inferences of the habits of action followed the reason-based logic explained above. The basis of defining the effective reasons for action were drawn from the process tracing interviews carried out in relation to the observations of clinical action. As in the study with the experts the behavioural and interview material were used to provide detailed timelines of the courses of the anaesthetists' actions. Comprehensive elaboration of the results will be presented in article under preparation (Norros & Klemola in preparation).

6.8 Summary of the results of young anaesthetists' habits of action

The above-described methodical steps were used to test the two hypotheses that we had formulated. The hypotheses focused on the development of expertise of the young anaesthetists during the 10-month follow-up period. The first hypothesis stated that a realistic orientation directs the interpretative use of information provided by the monitors. This would be indicated in the habit of action as rich use of situational information and as a tendency towards cumulative interpretations of the physiology of the patent. This was assumed to be accompanied by anticipation of the dynamics of the process in the control of the anaesthesia process and by a high level of preparedness in the use of tools.

Our second hypothesis concerned the development of habits of action during the follow-up period. According to this hypothesis, a realistic orientation would promote the development of habits of action through facilitating the application of theoretical knowledge with relation to situational information of the physiological functions of the patient. This would be indicated especially through a striving towards cumulative interpretations of the physiology of the patient in the habit of action, good conceptual mastery of the actionable knowledge and readiness to improve the theoretical bases of action, i.e. effective use of theoretical interventions by an expert.

We identified differences in the young anaesthetists' orientations. When the material from both the pre- and post- interviews was taken into account, we could state that the novices could be classified into three groups. There were anaesthetists who had a distinct realistic orientation. This orientation was qualified with an understanding of the particularity of the patient, the uncertainty of the process and the recognition of the mediated character of information. The second group of anaesthetists demonstrated an objectivistic orientation. Typical to this orientation was that the patient was seen as an "average man", and the uncertainty of the process or the mediated character of information were not recognised. We also identified an extreme form of the objectivistic orientation, which we labelled strong objectivistic orientation. Anaesthetists included in this group manifested clear features of an objectivistic orientation, which tended to strengthen during the follow-up period. Of the participants, 33% had a realistic, 45% an objectivistic and 22% a strong objectivistic orientation (Klemola & Norros 2002).

Participants with a realistic orientation had high values with regard to all criteria of habit of action. These anaesthetists thus appeared to cope appropriately with all four psychological core-task demands that the criteria were related to. Thus they clearly manifested an interpretative habit of action. Participants whose actions were characterised by an objectivistic or a strong objectivistic orientation received generally lower values with regard to all criteria, or they acquired occasional high values with regard to just one core-task demand. These doctors thus represented a reactive habit of action. (Norros & Klemola in preparation).

Because we were particularly interested in the participants' concepts and use of available information as the central psychological core task demand in this activity, we specified the connection between orientation and the use of information. It could be stated that the conceptual and interpretative mastery of knowledge was closely associated with the realistic orientation. The magnitude of the differences between orientations increased in direct relation to the proximity of the context where the tools were actually used. Thus, the differences were the smallest when the groups were compared with regard to conceptual mastery of monitor information, somewhat greater when compared with regard to the mastery of the constraints put on the monitor information, even greater when compared with regard to actionable knowledge and greatest when the use of information in actual situations was rated as part of the habit of action measure (Klemola & Norros 2002). The results are summarised in Figure 25. The results are based on all data and do not reveal the changes over the follow-up period.

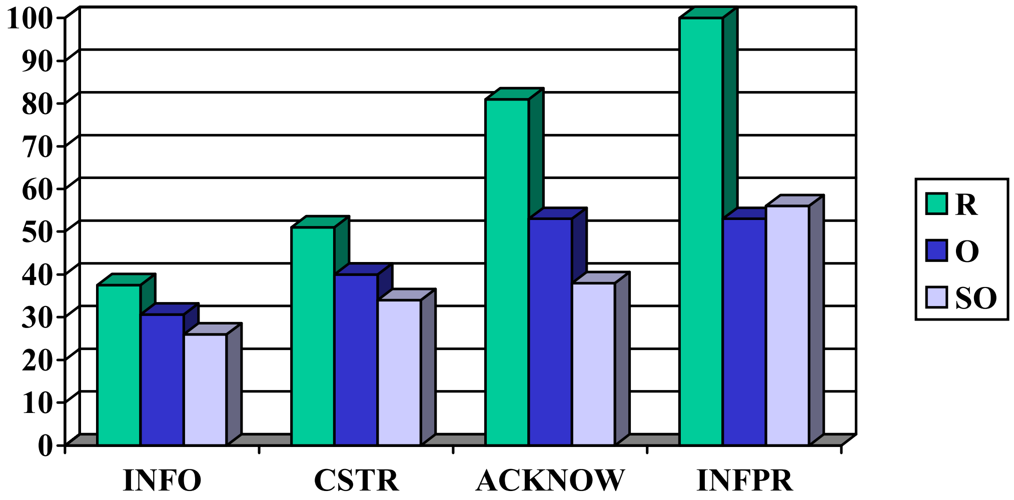

Figure 25. Mastery of monitor information (INFO), constraints on monitor information (CSTR), actionable knowledge (ACKNOW) and use of information in practice (INFPR) in three orientation groups Realistic (R), objectivistic (O) and strong objectivistic (SO) (Klemola & Norros 2002).

It appears that our first hypothesis, concerning the connection of the realistic orientation and the interpretative habit of action, gains support. The second hypothesis concerned the development of habit of action during the follow-up period has not yet been tested systematically. We have tentatively found a strengthening of interpretative habit within the realistically oriented group (Norros & Klemola in preparation). This trend appears to be connected with a tendency to cumulative interpretations, with a high level of mastery of actionable knowledge and a propensity to adopt actionable knowledge in interaction with an expert in the process tracing discussions. One of the realists manifested already in the beginning of the study a clearly interpretative habit of action, especially with regard to the operational dynamic demands. In this case the mastery of actionable knowledge was not particularly high and no improvement could be discerned in the overall measure of habit of action. With regard to this anaesthetist the realistic orientation was manifested in a high level of practical skill, but not in particularly high conceptual mastery.

As was indicated in Figure 25, the participants who were included in the objectivistic group had a lower mastery of actionable knowledge. However, within this group there were persons who appeared to have readiness to make use of the theoretical inference bases that were provided by the investigators during the process tracing discussions. This might be an indication of developmental potential. In one case this potential was realised in the development of the habit of action during the follow-up period. Participants who were classified as strong objectivists had a low level of mastery of actionable knowledge. These persons had less readiness to discuss the conceptual basis of actions during the process tracing interviews. We did not observe development with regard to habit of action in this group.

6.9 Trajectories of professional development: towards reflective or confirmative expertise

Reflective and confirmative expertise

We may interpret the results of our three-stage study of the anaesthetists' clinical practices to denote two main developmental perspectives of professional practice. The existence of these perspectives could be anticipated on the basis of the results concerning the experts. In the later study that focused on the young anaesthetists, we were able to identify some key elements of these two perspectives. The essential determinant of development appeared to be the person's relationship to the environment and to the object of activity. The results of the analysis of the novices' actions demonstrated that a realistic orientation is connected with an interpretative experimental way of acting. We characterised this way of acting by explicating its core-task orientedness and its adaptability which both are qualifications that were reasoned to concretise the underlying abductive dynamics of action in uncertain environments. The connection between realistic orientation and interpretative habit of action is strengthened by good mastery of actionable knowledge.

The results of our anaesthesia study are in accordance with the predictions of the theory of reflective thinking by John Dewey (1997). The observed form of practice promotes the construction of knowledge in a situation, which facilitates the control of the on-going process. The creation of knowledge in a situation is also the source of learning from experience and the prerequisite for accumulation of skills and knowledge. The described features of the daily practice project a developmental trajectory that we call *reflective expertise.* It is evident that the growth of expertise within this trajectory is not restricted to distinct events or demanding situations.

Our results also indicate that reflective expertise is not a qualification that would distinguish between experts and novices. It is not a feature that is related to a specific situation in the learning continuum. Instead, reflectiveness appears as habitual interpretativeness in the practitioner's action. This disposition is characterised by understanding the significance of focusing on the particular phenomena, which is therefore repeated in action. The construction of action is also shaped through taking into account the situational constraints and possibilities. The concept of "heedful interrelating" that was proposed by Weick and Roberts (1993) to characterise attentive practices of high-reliability organisations appears to have similarities with the practice that was qualified by realistic orientation and interpretative habits of action and that we assumed to open a perspective of reflective expertise.

The second perspective is characterised as a *confirmative expertise*. This perspective emerges from an orientation that was not found to facilitate attention towards the particular features of the situation. We interpreted this to be due to the fact that the patient and the process were conceived as representatives of general and already known classes of phenomena. Instead of being characterised through interpretative experimenting the observation of the state of the object takes a form of "recording" (Lipshitz 1997, Lipshitz in press). The practice is reduced to repeating of actions as mastered means.

Our results indicate that the novices manifested potential to adopt the reflective perspective to daily work. The prevalence of such a practice equalled its prevalence among the experts. This result corresponds with Ingold's theorising concerning the role of imitation as the major developmental process (Ingold 2001) in the communities of practice. However, this observation of the present situation should not lead to a pessimistic hypothesis of the future development of practice. We observed signs of development of practices in connection with the small-scale interventions that we induced during the observations of the actions in clinical situations. During the process-tracing discussions concerning the accomplishment of the particular anaesthesia processes, we aimed to make explicit for the actor the actions and their reasons and to provide conceptualised functional principles as bases of inference. Insight into the connection between actions and their reasons was expected to create new meaning relationships in action.

Development of expertise in an activity-system frame

In order to outline the developmental trajectories of the anaesthetists' professional practice we must consider our results in the activity-systemic frame. Several conclusions can be made that are relevant for the development of the activity. We summarise the conclusions in two major points. Firstly, we may state that the two habits of action and the related orientations become intelligible as general forms of anaesthetic practice in the present activity system. The objectivistic orientation and reactive habits are rooted in the prevailing philosophical conceptions of the neutrality and detachment of an objective science. This conception is considered as the central basis of medical practice (Klemola & Norros 2000). The prevailing epistemology of practice resembles that called the technical rationality. According to this basic belief, controlled and abstracted experimental conditions constitute the standard for the rigor of knowledge. Consequently, there might be a tendency to underestimate the informative potentials of clinical skill (Schön 1988).

Moreover, the prevailing concept of practice does not seem to take into account the fundamental difficulty of using statistical information as a basis for inferences in particular cases. Such inferences are, of course, the essence of clinical work. Silence about this central question may be a sign of interpreting clinical practice simply as application of knowledge. This would be a further characteristic of technical rationality. The observed enthusiasm in adopting technological solutions in order to improve the anaesthesia activity also denotes the technical rationality. Furthermore, we must also consider critically the attempts to develop evidence-based medicine and quality control systems. They have relevance for safety and quality control as they enhance the rigor and reliability of those aspects of actions that lend themselves to prescription. However, given the background of the prevailing epistemic orientation in the profession, the role of these means and measures for the development of the activity may easily be overemphasised. An appropriate treatment of the sicker and older patients puts demands on the adaptability of the practices.

The main source of adaptability in an open complex system is the human actor's competence to act according to the situational demands. Creating such competencies assumes science-based development of practices. New co-operative forms of action must also be created. Improving simultaneously the control for quality and safety and facilitating learning in the anaesthesia activity is the major challenge in the further development of this activity system. Analogous requirements were found to characterise ICT organisations that are making their business in very competitive situations and need diverse expertise and highly competent personnel. These organisations have a threat to become too bureaucratic and therefore learning is needed, especially processes that support reflection (Ruohonen et al. 2002).

Secondly, we see that the potentials embedded in the realistic orientation and in the interpretative habit of action resemble the demands set by the care of ageing surgical patients with more severe illnesses. This provides an activity-system founded argument for preferring this particular professional practice. The internal criteria for good practices originate in the needs of the patient and in the intrinsic constraints of the anaesthesia process. The used method opens up a possibility to create relevant means for training and qualifying practices through reflecting on what is understood as meaningful reasons for action and how these reasons relate to the functionally critical demands of the work. The scientifically educated professionals have a high-level theoretical competence, which is continuously updated through reading of scientific publications and through refresher training. Reflecting the meaning of behaviour through considering the habits of action is a way to bridge the gap between theory and practice.

Our finding concerning the two professional perspectives, the reflective and the confirmative, is theoretically interesting. It explains why some novices develop into real experts, whereas others, who might have the same amount of experience, do not. We claim that the difference is due to the described differences in the habits of mastering the daily work. Our results are not in contradiction with the well-known findings, which indicate differences between the performances of novices and experienced professionals. We may interpret those results as characterising differences in the actual actions of these two groups of practitioners, and as indicating that they manifest differences in the professional situations of these groups.

The anaesthesia study also allows conclusions with regard to the Core-Task Analysis method. These will be made in the next chapter, after we have first dealt with some further methodical and conceptual questions. These emerged in our studies in the maritime domain, which were carried out partly in parallel with the anaesthesia studies.

7. Habits of action as a cooperatively and historically formed practice in the navigation of ships

At the same time as we conducted our studies of anaesthesia we also investigated navigation of large ships. As in the case of anaesthesia, in navigation the actor is also directly involved with natural forces when controlling the domain process, the ship-sea system. The system may cause unpredictable control demands in each phase of the voyage. Steering of the ship and the control of its movements while simultaneously making use of the available sea area are effected by the complex interactions between the ship and the water, upon which the wind has a major effect. Perhaps the most salient feature in this interaction is the considerable delay between the steering operations and the actual movement of the ship. The larger the ship the longer the delay. Another important constraint is that the ship needs a particular minimum speed in order to be manoeuvrable.

Linked with steering, there is the need for knowledge of the characteristics of the water area from the point of view of providing safe routes for the ship to sail. This demand is connected with the task of piloting, which has traditionally been the responsibility of a pilot, an expert in navigation who is well acquainted with the local waters. According to a centuries old tradition, piloting expertise is in Finland maintained and developed as a profession that is organised by the state. A significant alteration in the legal basis of piloting took place in Finland when the new piloting law became effective in 1998. The new law introduced the right of bridge crews of both domestic and international ships to acquire the qualifications for piloting in Finnish waterways. Nevertheless, piloting is required for sailing in the archipelago routes and when approaching harbours.

Finally, the sea area is also part of a traffic system consisting of all the vessels sailing in the particular water area. The coordination and control of the movements of vessels sets increasing challenges in many densely operated waters. A completely new activity, called Vessel Traffic Surveillance (VTS), has recently emerged for supervision and control of the traffic in analogy to air traffic control in the aviation industry. Traditionally, the coordination among ships has been based on good seamanship and more recently on explicit agreements and rules established by national and international organisations.

Unlike all the other work processes discussed in this book, navigation has a long history. This has consequences for the profession and for how expertise is conceived within the community. The anthropological studies of navigation performed by Edwing Hutchins provided a valuable aid for the understanding of the history of navigation from the point of view of human cognition and action (Hutchins 1995). His studies have made the traditional way of navigating understandable to us, Western people, who tend to view navigation to be necessarily mediated by maps and other navigational artefacts such as compasses, radar or the Global Positioning System (GPS).

We had already earlier studied the steering of large vessels in difficult turns on a full-scale bridge simulator. Then, together with the Finnish Maritime Administration we conducted a field study on navigation of ships and decision-making in piloting situations in the restricted coastal waters of Finland. With this experience of the domain we joined an investigation of several marine accidents that had occurred for ships with a pilot on board on these same routes. The investigation was launched by the Finnish Accident Investigation Board (AIB).

Our studies in navigation manifest the same methodological development from cognitivistic-oriented approach towards an ecological one that we described in the previous chapters. Due to the peculiarities of the maritime domain some important methodological improvements emerged in these studies that completed the Core-Task Analysis theoretically and methodically. First, a more comprehensive analysis of cooperation became necessary. A further improvement was the acknowledgement of the need for a historical explanation for the existence of particular habits of action and, hence, the identification of the cultural-historical nature of habits of action. In the following we shall consider these two major advancements of the method.

7.1 Modeling the core-task of piloting

The developments of information technology provide new possibilities for the design of navigation equipment. Technically advanced equipment is retrofitted in old ships, and advanced technically integrated bridge systems are implemented in new vessels. The new tools have major consequences on the task of navigation by imposing changes in the representation of the navigation and steering tasks and by introducing new features in the distributed cognitive system (Hollan et al. 2000, Hutchins 1990, Hutchins 1995).

Already in our earlier studies concerning the use of new types of navigational aids we had made an attempt to analyse the task of the navigator from an ecological point of view. We were interested in how the navigational tools are used in practice when the actors interact with the ship-sea system. In these studies considerable effort was made to model the situationally relevant task demands and to create a context for the interpretation of performance and the use of available tools. In the first study (Heikkilä & Norros 1993) the usability of a predictor display was studied. This was a display that provided the navigator with the history of the ship's movements and a prediction of its future sweep. In our further study the usability of another navigational information system, an electronic chart display and information system (ECDIS) was examined (Norros & Hukki 1998). This system was designed to present navigationally relevant information regarding the hydrographic situation, the position and movement of the ship, and the traffic situation. The particular version of ECDIS that we tested was not integrated with a radar screen.

In the above-mentioned studies we observed that the challenge for the design and utilization of advanced information technological tools in navigation would probably be in designing the artefacts to allow a controlled transformation of the traditional navigational tasks into the context of modern maritime technology. The design of new equipment should be such that the relevant features of the situation would be highlighted and the necessary actions made as apparent as possible, i.e. the presentation of information would be navigationally informative (Norros & Hukki 1998, Woods 1995). Beyond this we considered it important that the information systems should provide the user with information of its own functioning, which is necessary for intelligent cooperation with the artefacts. Thus, the system's interface should display relevant information of its design basis and of the constraints with regard to its different operating modes. In critical decision-making situations the user could exploit this information. This generic demand on the navigational equipment was called system informativeness. Beyond informativeness, a central requirement for the information system was thought to be its reliability, ensuring the credibility of the system. Finally, as a result of the analysis of the features of the system in practice, its adaptability emerged as a central requirement, both in the sense of situational flexibility and the ability of the system to be developed according to operating experience. With these requirements in mind we constructed a framework for evaluation of the system.

The conclusion that we drew from the above-described simulator studies was that concerning the functionality of the tested equipment, the informativeness of the information was particularly significant. Informativeness relates to the way the task is represented and to the solvability of the task. We also observed that the compatibility between the representation of the task and the persons' ways of acting varied (Heikkilä & Norros 1993).

The studies also gave support to a further consideration mentioned by Hutchins (Hutchins 1995) that due to representation of the problem in different ways the artefacts also take varying positions in the organisation of tasks in the distributed cognitive system (Hollan et al. 2000). Hence, the cooperative and communicative constraints and the possibilities afforded by the tools were taken into account in the practices of the actors in more or less effective ways (Norros & Hukki 1998).

Therefore we concluded that the relationships between the informational characteristics of the information technological navigation tools and the navigational and cooperative practices of the ship bridge crews are research questions that would deserve further investigation.

Support for the critical role of the distribution of decision making among the navigation team and between the team and the navigational equipment may also be found from accident investigations. These provide almost the only available descriptions of navigational practices in natural environments. Thus for example the investigations carried out by the Finnish Accident Investigation Board (AIB) indicate that the ship bridge crews may have difficulties in interpreting the functioning of the navigation system (BalticMerchant 1998, Grimm 1997, Trenden 1998). Moreover, the investigations reveal deficiencies in communication and interaction between the bridge crew and the pilot (Anna 1993, Tallink 1997). A Canadian questionnaire study on cooperation on bridge in piloting situations indicated significant difficulties in communication on bridge (Canada 1995).

Analysis of action on the bridge in normal piloting situations and accidents

We aimed to clarify the above-mentioned questions in a study on decision-making on the bridge in piloting situations. Two different kinds of studies on this topic were conducted. In the first we focused on *normal piloting situations* in the Finnish coastal fairways.

Careful ethnographies of 17 normal piloting situations were carried out and observations of pilots and the bridge crews in their normal work were accomplished (Norros et al. 1998). The accomplishment of this study required a multidisciplinary research group, which consisted of expertise in the fields of navigation, marine technology and human factors psychology. The research group followed the pilots to the ships that required piloting. When we observed the piloting of an inbound ship it was necessary to use a pilot boat and board the ship out at sea, whereas when the ship required outbound piloting it was possible to enter the bridge while the ship was in the dock.

The other study was an *accident investigation*. It was focused on 10 accidents that, during a short period of time, had taken place in piloting situations in the same coastal routes where the previous study was carried out (Aurora 2000, BalticMerchant 1998, Christa 1998, Gardwind 1998, Gerda 1998, Grimm 1997, MarieLehman 1997, Norros et al. 2004, Nuutinen & Norros 2001, Nuutinen & Norros submitted, Trenden 1998). The two sets of piloting situations, the normal and the accident situations were basically comparable. The accidents had taken place in what could be called normal situations. About half of the cases were characterised by some difficult constraints, such as reduced visibility through fog, night conditions, strong wind, or frozen waterways in the winter. However, these navigational constraints are not exceptional in Finnish waters.

Hence, the vessels and their steering and navigation equipment were comparable in the material of the two studies, and the ships involved were in both cases equipped with variable levels of navigation technology. Our analyses of the steering and navigation equipment concentrated on the standard technology, which nowadays may also include an electronic chart.

The Core-Task Analysis methodology was applied in both studies. It was, however, adapted to the goals and to the type material of each study. Thus, with regard to the normal situations we were able to collect detailed data of the voyage through observations, video-recordings and interviews with the pilots and bridge personnel. In the accident investigations the courses of the voyages and actions of the personnel were reconstructed on the basis of the ship's logs, the sea protests and court interviews. In accident investigations it is natural to focus on a causal analysis of the event, but the material also provided possibilities for inferences regarding habits of piloting. Unfortunately, however, the accounts of the pilots and the bridge crew regarding the details of the course of actions had to be inferred from the official investigation material that did not include comprehensive interviews with the persons involved. In the analysis of the normal piloting situations we concentrated on the identification of habits of action on the basis of the observation of the courses of action and the interview material that was collected during the voyages. We took selected parts of each voyage that were considered to be demanding by the navigational expert of the research group, and collected the pilots' and the masters' accounts concerning the coping with these passages of the voyage.

The research aim of these two studies was to conceptualise the core-task demands of navigation in piloting situations and to generate knowledge for improving the safety of marine transport in the coastal waters (Norros et al 1998, Nuutinen & Norros 2001, Nuutinen & Norros submitted). In the following we shall demonstrate the use of the Core-Task Analysis inference scheme in these two studies for accomplishment of these aims.

The object and motive of piloting activity

In both studies we started by performing an actual-empirical analysis of each piloting situation. Then activity was analysed from the point of view of the actions of individual persons and ship bridge crews in these situations. Therefore, the conceptualisation of the *object of piloting activity* was initially rather abstract. It was defined as efficient navigation and steering of a ship in a sea area, in which task comprehensive knowledge and experience concerning the local conditions of the sea area are necessary for safe, economic and environmentally acceptable sailing of a ship to the desired target. Only later, when analysing the constraints and prerequisites that the organisations involved with this activity provided for piloting, and when reflecting on these constraints and prerequisites in the historical perspective, it became possible to construct an activity-system model of the piloting activity.

Modeling of the piloting situations

The tasks of the bridge crew and of the pilot in a piloting situation are oriented towards fulfilling the situational goal, i.e. normally towards sailing the ship safely into or out of the harbour via a particular route. In doing this, the pilot and the bridge crew must take into account the situational constraints of the task. In the study regarding the normal piloting situations we constructed a model for each studied piloting occasion (Norros et al. 1998). The models consisted of tables including items that were considered as significant constraints for action. These items were classified under the following categories: the ship, information and steering resources, personnel, the pilot, external conditions, and others. Under each of these headings several items were included. The models were based on information that we were able to acquire through observations and from the documents available on the bridge while we were present as observes on the bridge. The marine engineer and the navigating expert of the research group collected the information necessary for the construction of the situative models of the domain.

The above mentioned categories of constraints were also taken into account in the analysis of the marine accidents. The domain model was improved by adding an important further constraint, the fairway. Detailed analyses of the geometrical constraints for making turns in particular phases of the route, and of the marking of the fairway in these turns, were carried out by the navigating expert of the investigation board. Many of the waterways of Finland are hundreds of years old traditional sailing routes. During the investigation it became evident that in some of the turns of the fairways the prerequisites for safe turning for large ships were not fulfilled. It also became clear that in some cases new rocks had been found that were neither indicated by buoys and beacons nor marked on the charts. This fact characterises the challenges that the Finnish waters put on sailing. There are innumerable rocks that are discovered gradually one by one[11]. The navigational expert of the investigation team developed an evaluation procedure for the analysis of the fairway geometry and route marking from the navigational point of view (Norros et al. 2004).

[11] The Finnish sea charts are considered as excellent world wide. In the summer of 2001 a work was completed, during which all the Finnish sea routes were once again re-charted with the aid of most advanced technological means.

Decomposition of the piloting task

The task of navigation and steering in piloting situations was analysed first from the navigational point of view. The significance of the cooperative aspect of the task emerged in a later phase of the analysis. We used the action-regulation approach of Winfried Hacker, according to which the task may be decomposed from a hierarchical and sequential point of view (Hacker 1998). The model of the piloting task is presented in Figure 26. The solid arrows refer to the hierarchical structure and the dashed ones to the sequential structure of the task.

In the model of Figure 26 the hierarchical structure of the piloting task refers to the responsibility relationships within the task. The shipmaster always has undivided command and responsibility for the ship. This responsibility may be situationally divided into responsibilities for different functions. In the piloting situation the responsibility for piloting is on the bridge, where the decisions concerning the goals for the actual navigation action are defined and the management of the action accomplished. Within this responsibility, the route, the actual goals and the situational division of labour must be decided. The global task is further divided sequentially into four major sub-tasks, including piloting, navigating, steering and surveillance.

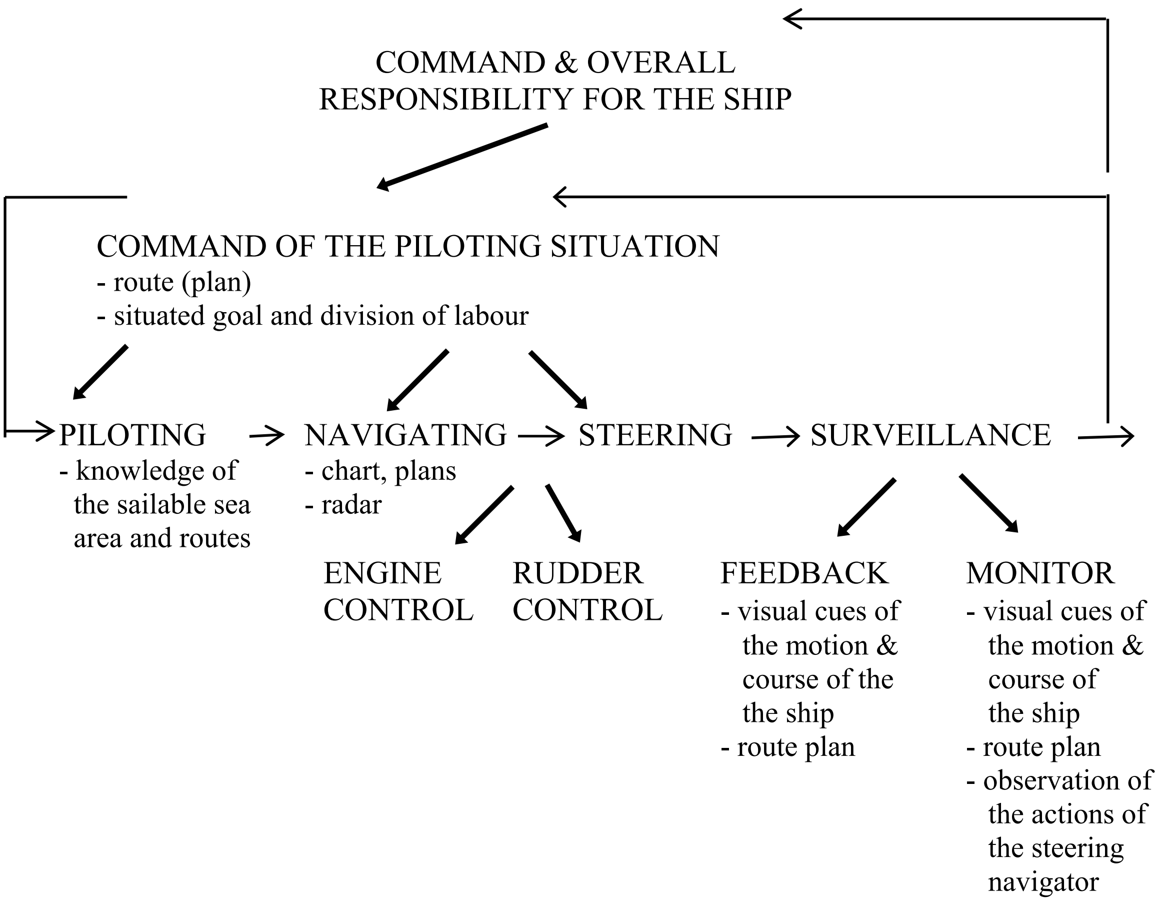

Figure 26. Hierarchical and sequential structure of the navigation and steering task in piloting situations (adapted from Norros et al. 1998).

It was found relevant to decompose the steering task further into control of the rudder and control of the engine. The surveillance function consists of the follow-up of the navigation and steering operations. It may be organised in two ways, either integrated in the action or by monitoring. The latter implies control that is performed externally by a second actor. The monitoring task provides an extra check of the accomplishment of the goals of the task and it is motivated through the high reliability demands set on the piloting task.

The way of decomposing the navigation task and the actual division of work in piloting situations interacts with the technology used. This is due to the fact that the artefacts determine the way in which the task is represented (Hutchins 1995). In our study on normal piloting situations we tackled this question by observing the division of the navigation tasks depicted in the above model (Figure 26) in the accomplishment of the tasks by the navigators and pilots in actual situations. The availability of navigation technology and the composition of the bridge crew were also considered. When conducting this analysis we took into account the two distinct forms of piloting that the Finnish routes require, port piloting and sea piloting. The former comprises manoeuvring of the vessel in the harbour area, whereas sea piloting refers to assisting the ship through the archipelago area. Piloting is not required in the open sea. Depending on the location of the harbour the sea piloting part may sometimes be several hours long (up to seven hours), but in some cases the sea piloting only takes half an hour. In sea piloting, the positioning and mastering major turns are the critical tasks.

The results of our observations in normal piloting situations indicated that there are several ways of dividing the task and using the technical resources and the personnel. We called these different structuring of the task piloting methods, and distinguished four different methods for port and three for sea piloting (Norros et al. 1998). All the port piloting methods were based on manual control of the ship. They differed with regard to how the situational command was organised and to the responsibility for the manoeuvring tasks. The dominant methods were characterised by having the pilot in charge. He was assisted either by the shipmaster alone or by the master and the helmsman.

The observed sea piloting methods could be distinguished according to the use of automation, i.e. either steering was manual or an autopilot was used. In the first sea piloting method the pilot was in charge of the situation and navigated with the assistance of the helmsman while the master was monitoring. In the second method the pilot was in charge of the situation, he steered the vessel by using the autopilot and the master was monitoring. The third variant was the opposite of the second, i.e. the master of the ship was in charge of the situation and used the autopilot whereas the pilot monitored the situation. The second and third methods may seem symmetric but when taking into account the level of acquaintance with the route, the monitoring carried out by the pilot has a far greater relevance because the pilot is acquainted with the sea area. The second method was clearly dominant.

Our results indicated that with regard to both the port and sea piloting the dominant methods were pilot-centred, i.e. the pilot was in charge of the situation and was steering (Norros et al. 1998). The result was counter to the expectations of the maritime authorities, who had interpreted the piloting task on the basis of the legal norms that clearly prescribe responsibility for piloting to the ship master and define the pilot as his assistant. According to our results, the (implicit) choice of the method was clearly not related to the availability of a particular navigation technology or to the availability of personnel. Instead, characteristics of the technology and of the personnel were taken into account by the pilots within the frame of the prevailing piloting practice that the dominant methods could be interpreted to represent.

It was also concluded that due to their nature the piloting methods put special demands on communication. With regard to port piloting the communication demands were related to managing the distributed manoeuvring task. With regard to sea piloting, communication demands were connected to anticipation of the route and managing turns. In making turns, the accomplishment of an adequate monitoring action is important for control of the continuously rotating ship. However, course changes are not easily monitored without communicating intentions when the navigator operates an autopilot. Despite this clear demand for communication, our results from normal piloting and those of the studies referred above indicate that communication is limited in piloting situations. A similar message is conveyed by the results of our own accident investigations and by reports from other investigations (Canada 1995, Norros et al. 2004, Tallink 1997).

In the accident analysis the modeling of the task was improved by including a description of the usability of the navigation and steering equipment. The analysis focused on the navigational and system informativeness of the systems that are in normal use in coastal navigation and piloting. In this analysis the equipment was also evaluated from the point of view of the constraints they put on, and the possibilities they offer for co-operation on the bridge (Norros et al. 2004).

The important navigational advantage that most developed steering and navigation systems provide is that they facilitate the accomplishment of carefully planned and highly controlled turns (Larjo 2000). This advantage of the navigation systems becomes significant when making turns in narrow fairways. The safety margin of the narrow waterways decreases even more as the ship size increases. Exploitation of the benefits of the new equipment does not take place automatically. Instead, the new technical possibilities must be embedded in the practices of the navigators. Because the potential usefulness of the equipment is greatest in restricted waters where the use of a pilot is necessary, the tools also challenge the cooperation between the bridge crew and the pilot.

It is planned to perform a development of this usability analysis framework in cooperation with the navigation expert of the investigation board who carried out the analysis of the navigational equipment in our accident analysis. We also plan to build on our earlier work on the evaluation of navigational equipment and other complex systems (Norros & Hukki 1998).

Core-task demands of piloting

According to the CTA methodology the description of the core task requires setting the situational goals, conditions and the sequential structure of the task in relation to the generic outcome-critical functions that should be maintained to ensure a successful interaction with the domain. As a result the core-task demands of the task should be acquired.

The ship-sea system forms a unit in which the vessel and the fairway define each other mutually, whereby the constraints for navigation emerge. Therefore, a safe and efficient navigational performance requires integration of knowledge regarding both the hydrodynamic features of the vessel, including its navigational and steering equipment, and the characteristics of the available waters and fairways. On the basis of a conceptual analysis of the physical ship-sea system we ended up with three critical navigational functions which have an effect on the mastery of the system and on the safety and efficiency of sailing (Norros et al. 1998, Nuutinen & Norros 2001). We identifired the following outcome-critical functions of piloting:

- The uniqueness of the ship-sea area system and uncertainty of the hydrodynamic processes
- The dynamics of a moving system and the delay in its control,
- The complexity of the system due to the diversity of representational forms of the process information (direct and technically mediated) and the integration of knowledge from two different professional backgrounds.

In the conceptualisation of the outcome-critical functions we made use of the generic model of the environmental constraints that was proposed in Chapter 2 (Figure 1). Figure 27 illustrates the use of the generic model for modeling of the core-task of piloting (see also Nuutinen & Norros submitted). The outcome-critical functional demands are depicted in the corners of the triangle.

In navigation on the open sea the positioning of the ship is necessary for maintaining orientation. Therefore the position is determined at frequent intervals and the result is plotted on a chart either manually or electronically. From the point of view of piloting the ship the present position is not operatively relevant. Present is already past information for steering and navigating. Hence, in piloting, it is more significant to anticipate the future position and the course of the ship because the goal is to steer a moving vessel in a restricted area often with very small safety margin. Hence, it is significant to identify free water areas and to steer the ship, which moves with considerable delay, through a clear fairway. The turns provide the most difficult challenge for piloting. The critical information for a safe turn consists of the present course of the ship and the targeted course (Larjo 2000).

In the light of the critical functions of piloting it was possible to elaborate the *sequential structure of the navigation task* in piloting situations. We may assume that both the pilot and bridge personnel accomplish *preparations for the piloting* which facilitate coping with the demands of the domain. These preparations focus e.g. on anticipation of the route, on the clarification of the characteristics of the vessel, on the personnel, and on the examination of weather conditions. Further, we may notice that in the beginning of each piloting there is a distinct initiating phase during which *the co-operative situation is constructed* through the interaction of the two parties involved the bridge crew and the pilot. In the current practices these two first phases of the task are usually accomplished in an implicit way. However, they provide both the navigational and the cooperative prerequisites for the performance. The third phase of the piloting task is the actual navigational task performance that we labelled *co-operative navigation and steering during piloting* (Norros et al. 1998). A decomposition of the navigation task was presented above (see Figure 26). Several tasks within the other two phases were tentatively identified in our study on normal piloting situations.

In the actual task performance the critical functions are balanced against each other by the actors in the process of taking into account the situational constraints and possibilities of action. In order to be appropriate adaptability is required from actions. In the core-task model of Figure 27 the balancing between the core-task demands in adaptive action is depicted.

It is assumed that adaptability of action in DCU-environments requires particular qualifications of skill, knowledge and collaboration. These are ingredients of appropriate practices. Corresponding models that demonstrate the connection between the critical functions and the psychological demands whereas first constructed for the nuclear authority activities (Reiman & Norros 2002) and for maintenance work (Oedewald & Reiman 2003, Reiman & Oedewald 2002b).

Feel of the ship's movement in the environment (see Figure 27) refers to the very fundamental psychological demand that piloting sets on the navigator. This feel relates to perceptual-motor comprehension of the connection of the steering operations to the ship's movements in the water. The necessary feel also includes a comprehension of the position of the ship with regard to the environment. The water area must be deep enough and free from obstacles, i.e. rocks, islands, or other traffic. The routes provide the boundaries of safe sailing and the traffic must be observed. The wind conditions have an important effect on the boundaries of safe sailing on a particular see area. The navigators develop a feel of the distances and rates of turn that allow an adequate travelling in the sea area. The advantage of the pilots is that they have become acquainted of the see area by sailing with various kinds of ships so that they have built up a feel of the fairway. Their disadvantage may be that each ship has hydrodynamic peculiarities that a non-frequent navigator may have difficulties to perceive in normal sailing.

Anticipation may be seen as one of the essential psychological demands on piloting. With reference to the above-presented triangular model of the core-task of piloting (Figure 27), anticipation may be conceptualised as a feature of the required piloting skill and it balances between the constraints set by the moving vessel and the uncertainties of the system.

The navigational knowledge necessary for the mastery of the outcome-critical functions has traditionally been distributed between the ship bridge crew and the local sea pilots. In the frame of the prevailing professional structure a shared action between the representatives of these two partners seems necessary for safe sailing. Drawing on the ideas of Hutchins the following psychological core-task demands may be derived with regard to cooperation in piloting (Hutchins 1990, Norros et al. 2004, Nuutinen & Norros 2001, Nuutinen & Norros submitted).

The first important cooperative demand is the *transparency of performance*. This demand denotes the need for perceiving the on-going task performance on the bridge. There are at least three factors having an effect on the transparency of performance. These are the *transparency of the goal, the transparency of interaction and the transparency of artefacts*. An example of making the navigational goal transparent would be the use of an explicit route plan that defines the difficult phases of the fairways, especially the geometry of the difficult turns along the route. The repetition of the master's or the pilot's commands regarding bearings by the helmsman and the latter's statements of the achievement of the desired course are examples of the transparency of interactions. When the helmsman is not used in navigation the transparency of interaction may be enhanced by the shipmaster's or the pilot's information about their intentions before turning. The transparency of artefacts refers to the possibility of all actors to observe how equipment is used and how the instrument and the system respond to the operation. The functioning of the standard autopilot, for example, is rather non-transparent. Hence, its use would require verbal mediation of intentions on the part of the navigating person. With regard to the core-task model of piloting (Figure 27) we have conceived the transparency of the goal to be related to coping with the demands put by the moving vessels and as an aid for anticipation. The setting of goals is simultaneously an instrument to cope with uncertainties of the system. The transparency of interaction and the transparency of artefacts were considered to relate to coping with the dynamics of the moving vessel and with the representational complexities of the domain, and hence they constitute qualifications of cooperation demanded in the piloting task.

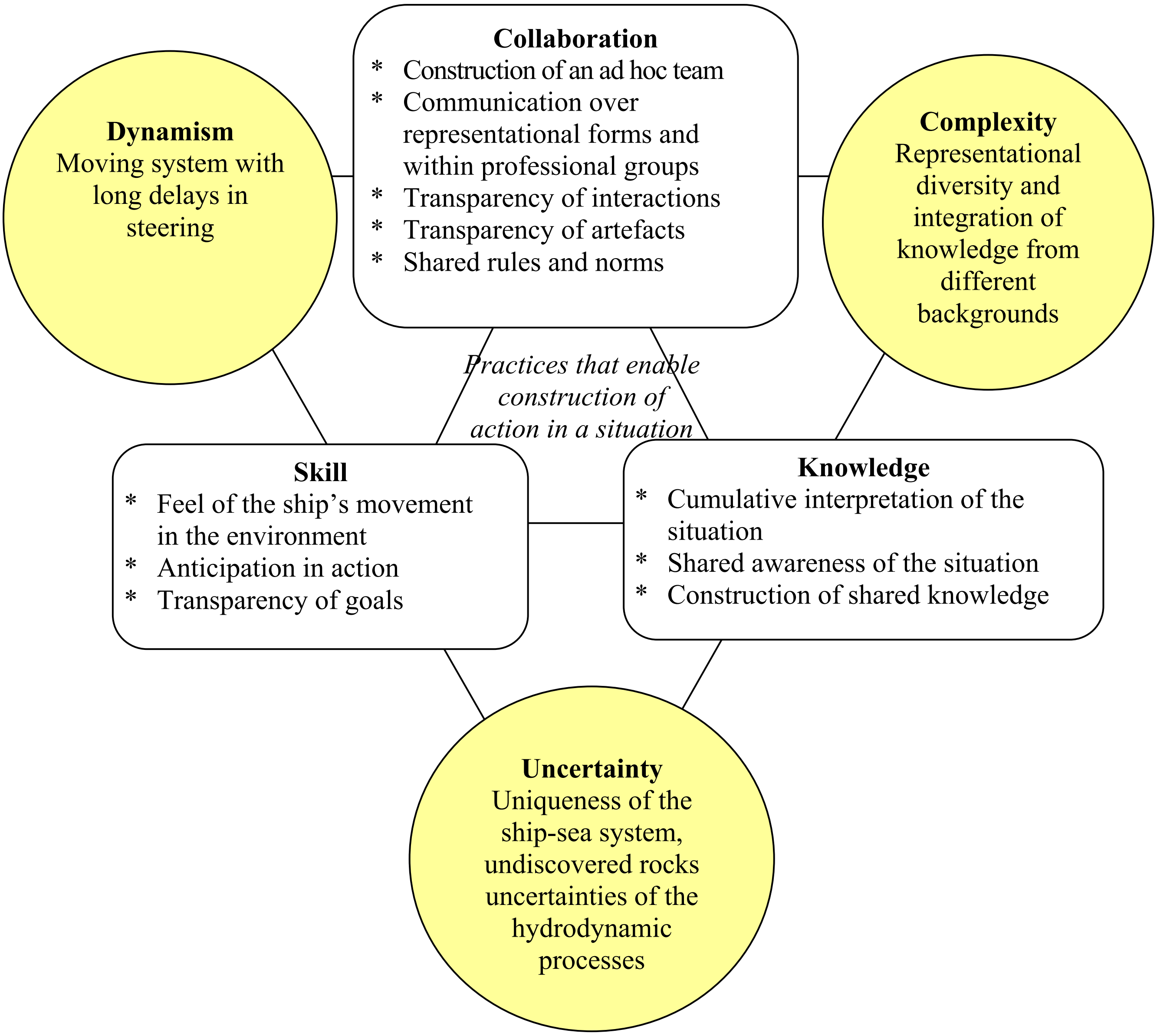

Figure 27. A core-task model of the piloting activity includes the outcome-critical functions of piloting and the psychological core-task demands.

A significant core-task demand on piloting that has connections to the complexities of the control of the moving system is the *construction of an operative ad hoc team*. In piloting, it is required that the pilot and the shipmaster consider the different pre-requisites for co-operative action, i.e. the manning, the navigation and steering equipment, and the weather. By taking all these different factors into account a situationally appropriate solution for the structure of cooperation may emerge. The formation of the ad hoc team also includes creating an atmosphere of mutual respect and trust.

A further cooperative demand that we suggest is the *creation of common rules and norms and commitment to them*. The need for maintaining this function is particularly pressing in DCU-situations, in which several independent actors participate in the same activity. As every transportation system also a maritime system sets the requirement of shared norms and commitment to them. In the core-task model this demand was included as a feature of the cooperative demands balancing between the dynamics of the system and its complex structure.

Related to the coping with the complexities of the system and to its uncertainties, several knowledge-related core-task demands emerged. Most important appeared to be the *construction of a cumulative interpretation of the situation.* This psychological core-task demand expresses the need to balance between the uncertainties of the system and the complexity of its collaborative structure. Making interpretations requires active use of available navigational information, which may be acquired by direct observation of the environment and the movement of the ship and by making use of the information mediated by the steering and navigation equipment. In the latter case the taking into account of the various technical constraints of the artefacts is necessary for an adequate interpretation of the mediated information.

In order to be appropriately operative in a piloting situation the interpretation must be shared among the bridge personnel. Thus the need for *maintaining a shared awareness of the situation* throughout the voyage emerges. There are several means to enhance shared awareness, the most important of these being the existence of and use of common route plans, communication of intentions, and effective utilisation of the features of modern advanced steering and navigational equipment.

Another collaborative demand related to the parallel coping with the uncertainties of the system and its structural complexities is the need for active construction of a *shared knowledge base and experience* among the participants in piloting. The members of the bridge crew and the pilot should have at least partly overlapping knowledge in order to be able to understand and interpret the other partner's intentions, and coordinate own actions with that of the other. A shared knowledge base facilitates for example the ability to identify the other actor's need for help, which in turn is a prerequisite for timely offering of help. The development of insight into the on-going task is important because the need for help is not necessarily expressed readily by professional actors.

Indictors for habit of action in piloting

The core-task demands described above (and in Figure 27) were used as bases in deriving a first version of habits of action indicators for piloting practice. Both the results of the on-board observations of normal piloting practices and accident analysis data were used.

With regard to the CTA-inference model of Figure 19 the determination of the indicators represents the *analysis of habits*. It aims at creating *indicators and criteria of habit of action,* which portray what could be comprehended appropriate action. The indicators and criteria are derived by analysis of how the abductive dynamics of action, that facilitates the adaptability to action, may be achieved in the particular DCU environments. The required adaptability becomes visible in the real perception-action cycles under particular constraints and possibilities. In the analysis these are set in relation to each other to infer the indicators.

By making use of the sequential task description of the piloting task, significant elements were identified on the basis of which relevant operations could be defined and analysed further. As a result we acquired indicators for the evaluation of habits of navigating and cooperation (Norros et al. 1998). In a further version of the indicators also indicators that express the actors control of their own actions were added. All together 27 indicators could be defined (Nuutinen & Norros 2004). As we explained in the previous chapter, the behavioural indicators for habits of action are graded according to how much these behaviours manifest tendency towards either to interpretativeness or reactivity of interaction. This evaluative dimension expresses the underlying abductive dynamic of action, which denotes the situative appropriateness of the whole task performance. When extracting relevant operations and identifying their possible significance for action we made use of the actors' accounts of their performance and the navigation expert's judgement. We faced difficulties in this task due to the deficiency of data of actual courses of action and corresponding accounts of the navigators about the reasons for action. Neither of the present studies provided sufficient data for this evaluation. However, even with a tentative version of the instrument we obtained important results regarding the actual fulfilling of the core-task demands. The most important results will be summarised in the following.

7. 2 Results concerning the piloting practices

Results of the normal piloting situations

In the analysis of *normal piloting situations* we evaluated each piloting performance according to a number of phase-related subtasks using simple dichotomous evaluation categories implicating the degree of fulfilment of each task aspect (Norros et al. 1998). The estimation of how well the navigators took into account the critical functions of piloting and, hence, of their fulfilment of the core-task demands of the work consisted the following items: the transparency of the used piloting method, the use of route plans, the pilot's and the master's prior knowledge of the ship or the fairways. These evaluation items for piloting practices were cross tabulated in order to acquire a comprehensive conception of the type of practices that are typical in normal situations. The result is presented in Table 17.

In summary, the results indicated that in 6 pilotings (the bolded figures in the table) out of 17 the prerequisites for a shared awareness of the situation were deficient. This was either due to non-transparency of the piloting method and/or to the deficient explication of the route combined with deficient prior knowledge of the fairway or the ship. In a number of observed piloting situations the actions were based on assumptions instead of on verified knowledge or on a shared understanding of the situation. We characterised practices qualified with the above-mentioned features as risk-prone. The analysis of navigation performance was based on careful analyses of the actual courses of action but the characterisation as risk-prone was made with the aid of a habit-centred vocabulary defining features of practices. Our characterisation provided a diagnosis of potential problems within the practices. This potential could become real under unexpected or more demanding conditions. In only 3 cases out of 17 were the pre-requisites for safe navigation clearly ensured by the quality of the practices of the navigators.

All the piloting cases took place in comparable external conditions. Thus, the actual conditions did not appear to determine the quality of practices. Furthermore, we may note that the piloting tasks were completed successfully in all cases. Hence, the results of actual courses of action were not as such informative in the evaluation of the practices.

Table 17. The fulfilment of prerequisites for creating a shared interpretation of the navigational situation. The first number in each cell refers to the number of cases and the bolded number to the number of cases in which prior knowledge of either ship or the fairways was scarce. The texts in the cells provide an interpretation of the availability of prerequisites for shared awareness of the situation during piloting (Norros et al. 1998).

		Explication of the route by the navigators	
		No route plan or discussion about the route	A route plan was available, or either of the navigators (the pilot or the ship master) initiated discussions of the route
Transparency of the used piloting method (piloting practice)	Non-transparent	6 / **3** Insufficient prerequisites for the formation of a shared awareness of the situation	3 / **1** Moderate prerequisites for the formation of a shared awareness of the situation; reliance on assumptions that actions were understood by the other actors
	Transparent	5 / **2** Partly insufficient prerequisites for the formation of a shared awareness of the situation, reliance on the assumption that either actors were familiar with the route	3 Formation of a shared awareness of the situation was ensured by the navigators

We also investigated the task characteristics for which the six most risk-prone piloting cases had received low evaluations. These six cases received minimum points in the following elements of evaluation of habits of action.

- Evaluation of the navigational characteristics of the ship with reference to the piloting task
- Preparing and planning of own actions
- Interchanging of information
- Use of pre-evaluations and plans
- Informing about changes in the navigational performance on the bridge
- Clarification of the movements of the other ships, informing other ships of one's own movements
- Ensuring the transparency of one's own actions
- Ensuring sufficient monitoring.

The results indicated that with reference to the psychological core-task demands, typical of the risk prone piloting was that in the preparation for piloting the pilot oriented towards rehearsing his own knowledge of the route, which is of course important. However, the preparations did not contain clarification of ship-specific prerequisites, nor did they focus on features that would promote cooperation on bridge, e.g. the pilots were not observed to equip the bridge crew with charts or plans to be used to communicate with the masters of the ships. Second, during the piloting, such actions that would promote the formation of a shared interpretation of the situation or would facilitate the transparency of actions were neglected. Furthermore, communication of intentions as a necessary prerequisite for adequate monitoring was scarce. However, the practices were well tuned to cope with the pilot's individual mastery of the navigational basic requirements, such as anticipation of the ship's movements and making cross checks.

Only in three piloting cases were the basic preconditions for a shared awareness of the situation available. Hence, our conclusion of the analysis of the material from the 17 successful normal piloting performances was that the cooperative demands were not comprehended by the navigators as inherent contents of the core-task of navigation in piloting situations.

Results of the analyses of accidents in piloting situations

The results of the 13 *accident* analyses provided further support for the above conclusion. In the investigated cases the external conditions were in average more demanding than those we observed in the normal performances. The main difference in the conditions was that in the study of normal piloting we did not happen to encounter situations in which the visibility was severely reduced. Notwithstanding the difference in the external conditions the piloting practices appeared to have been very similar. The features of "pilot-centredness" and individual orientation that characterised the piloting practices in the normal situations strengthened during the voyages ending in accidents as the situational demands increased (Norros et al. 2004, Nuutinen & Norros 2001, Nuutinen & Norros submitted). This observation indicates that it is not easy to change practices ad hoc even though the limitations of the practice may appear evident. Hence, the normal navigation practices must be such that they embrace the necessary potential for handling the critical constraints even though this potential is not demanded daily.

In the accident cases, the dominating practice in piloting appeared to be based on a concentration of tasks to the pilot in charge of the piloting situation. The role of the master tended to be reduced to a rather superficial monitoring. The flattening of this important task was due to the lack of adequate reference for monitoring. In low-visibility situations, which was the case in some of the accidents, the conditions hindered the use of visual reference. Because route plans were also not available they did not provide any reference for monitoring. Hence, it was concluded that the lack of plans was a significant contributor to the accidents. Such plans for critical turns were not available in the normal piloting cases that we observed, either.

Our results give rise to the following question: If the requirement for cooperation is so evident in piloting situations, what is the explanation for the clearly deficient communication and cooperation? Could it be that cooperation is not considered as a central content of the core-task of navigation in piloting situations?

7.3 A historical perspective to the piloting practice

There is an evident need to find reasons for why the cooperative actions that appear necessary for safe and efficient piloting are clearly neglected in the current navigational practice. The analyses we carried out within the accident investigation seem to shed some light on this question.

As indicated above, the investigation group had profound competence of the domain allowing us to carry out a detailed domain-informed analysis of the usability of the layout of the bridge and of the information characteristics of the steering and navigation equipment of the bridge. These analyses were partly included in the case- by-case investigation reports (see e.g. BalticMerchant 1998) but they will be conceptualised further in a summary report of the investigation (Norros et al. 2004). The results may be crystallised into three points (see also Nuutinen & Norros submitted).

First, it was found that the acting navigators in piloting situations, mainly the pilots, experienced difficulties in using the standard steering and navigation equipment effectively. Thus, the foremost advantage of the new navigation technology, i.e. its potential to promote planned and highly controlled turns, was not exploited efficiently by the pilots. This neglectance of the evident benefit of the navigation technology was due to the fact that the pilots were not acquainted with the navigational concepts and procedures necessary for making the geometrical plans for turning, which would be required for efficient use of the properties of the new technology. The masters, who were used to sailing on the open sea and therefore did not need to worry about turning geometry, were on average not better qualified for applying the new artefacts for piloting. Consequently, navigation in piloting situations was based on private and implicit methods of turning and on the utilisation of direct visual information. Cooperation with other persons was minimal in this way of piloting. As indicated above, a fixation on this way of piloting occurred when the constraints of piloting became more demanding (Norros et al. 2004).

Second, it could also be observed that the properties of the steering and navigation equipment, especially those of the radar, were not designed with the particular demands of the piloting situation in mind. Therefore, operating the equipment in the piloting situations was clumsy and the lack of functionality directly hindered the task performance in certain weather conditions (Norros et al. 2004).

Third, we recorded cases in which neither the pilot nor the master considered the existing norms that prescribe constraints on navigation equipment with regard to weather, route or manning.

The historical analysis of the traditional navigational practices in the Micronesian islands by Hutchins (1995) opened up a perspective for the interpretation of our the results regarding the current Finnish piloting practices. Hutchins contrasted the Micronesian type of navigation with the Western open sea navigation in the following way.

"The Micronesian navigator holds all the knowledge required for the voyage in his head. … In the Western tradition, physical artefacts become depositories of knowledge, and they were constructed in durable media so that a single artefact might come to represent more than any individual could know" (Hutchins 1995, p. 96).

In his analysis Hutchins showed that it is computationally less expensive for the Micronesian navigator to let the surrounding move around him, whereas in the Western technically mediated navigation that makes use of an analogue-to-digital conversion and arithmetic computations, the navigation task is accomplished more effectively on the chart. Hutchins stated further that modern navigation practices are of rather recent origin. The navigational practices in European waters resembled a rather unsophisticated version of Micronesian navigation before the introduction of the magnetic compass around 1100 AD (Hutchins 1995, p. 93).

A cursory historical analysis of piloting in the difficult coastal waters of Finland revealed that the particular constraints of the Finnish waters on the one hand, and the socio-historical conditions of piloting as a profession in this country on the other, have probably facilitated the perseverance of the features of the traditional navigating practice described by Hutchins as the basis of navigation in piloting (Norros et al. 2004). Our analyses indicated that knowledge of piloting an important factor for the security of the country and was therefore a highly valued secret skill. Piloting has through its history been strongly tied with individual actors, and piloting skills have been mediated to the next generation in an apprenticeship relationship from father to son.

It appears that the more recent possibilities for use of charts and radar in navigation did not cause much change in the traditional ways of navigating by the pilots. Radar was used in the head-up mode, in analogy with the proceeding of the ship, and the chart was mainly used as a back up for own memory of the routes. Our analyses indicated, further, that in the early phase of implementing radar it was normal to have only one radar on the bridge. We have reason to formulate a hypothesis that whereas the use of radar did not change the way of navigating it probably changed the cooperation on the bridge in such a way that the monitoring function came to be neglected in radar-navigation. The deficiencies even in the current cooperative actions may reflect this tradition, notwithstanding the fact that two radars are usually available on the bridge.

The regulations regarding piloting define the general procedures for work on the bridge and the principles of route planning. According to the interpretation of the Investigation group (Norros et al. 2004) these prescriptions do not function in practice due to a deficient control of their implementation.

7.4 Definition of the zone of proximal development for the piloting activity

The contradictions in the present piloting practice

With the aid of the gained insight into the historical origins of the navigational practices the board of investigators was able to elaborate the initial assumptions concerning the problems in the navigational practices in piloting situations. By piloting practice we mean the pilot's ways of interacting with the ship-sea system. This interaction is qualified by navigating and steering operations that are accomplished in cooperation with the bridge crew, and by making use of the available resources. The piloting practice may be considered as expressing habits that are constituted by experience and training within the community of practice. This practice is historically formed. In the case-to-case examination of the courses events leading to accidents the piloting practices were conceptualised and decomposed into two parts: the way of navigating, and the way of cooperating in piloting.

The way of navigating referred to how information from the environment, from the navigation equipment and the socially communicated information are utilised in steering and navigation. The way of navigating must be considered both by analysing situated actions and by putting the actions in their historical perspective. As a result of the conceptual analysis of the investigation material, two basic ways of navigating were identified, *traditional and the technology-mediated navigation*. The traditional way is based on an 'inside-out view' of the environment. It was the natural way to navigate when no technical tools were available. The traditional way of navigating resembles the characterisation made by Hutchins regarding the navigation method used traditionally in Micronesia (Hutchins 1995). The historically later, technology-mediated way of navigating is based on the real movements of the ship on the plane, which is locked to north. This way of navigating is based on an 'outside-in" or a "bird's eyes" view to the sea area.

The way of cooperating refers to the cooperative practices in the piloting situation that are necessary in the fulfilment of the navigational tasks. Our analyses indicated that communication on the bridge, communication between the bridge and the external partners – e.g. the harbour or the vessel traffic service – the use of the steering and navigation equipment, the number of the crew, the division of work, and the taking into account of the norms and procedures, constituted the important features of cooperation in the piloting situations. The way of cooperating is inseparable from that of navigating, and both are connected to the way the task is represented through the artefacts and to the ways of making use of the available tools.

The results of our analyses in the accident investigation indicated that the features of traditional piloting practice are dominant in the current practices of the pilots. Further, the results showed that currently there is strong pressure to reconstruct the practice to overcome the limitations of the traditional, individually oriented way of navigating (Norros et al. 2004).

A need to create a new type of absorbed coping in navigation

When considering the historically formed practices from the point of view of the critical functions of piloting the strength of the traditional way of navigating becomes evident. This practice focuses on the situatively changing particular features of the ship-sea system. The pilots often emphasised the necessity for orienting to the particularities of each navigating situation. They tended to reject attempts to regulate the performance through establishing more prescriptions. An interpretative relationship towards the navigational object is an inherent quality of the highly developed traditional piloting practice. The history of Finnish piloting also indicated that the technical artefacts might be used in a way that facilitates this traditional practice. Because this practice is almost completely tacit it is natural that communication and cooperative forms of work are irrelevant, and even disturbing.

The present technologically advanced navigation and steering equipment represent the navigation task in a computational form and analytical perspective. As we have indicated, making use of the technology in task performance is becoming indispensable in archipelago navigation. This is due to the fact that the technology enables a better control for turns under the strict constraints set by the fairways on sailing with large ships. However, appropriate use of the technology would require the construction and adoption of the new technology- mediated, explicit, conceptualised and cooperative navigation practice.

As indicated earlier the critical demand in piloting is to determine where and how to sail by making optimal use of the available water area. Anticipating the future course in the form of absorbed coping (Dreyfus 2001) rather than explicit procedures of positioning and planning appears to be an adequate way of managing the demands of the dynamic system. The traditional way of navigating facilitates such an absorbed coping. Therefore there are strong reasons not to reject this habit and the way of relating oneself to the environment. However, as we have shown, there is a competing need to make use of the pre-planned turning procedures. Balancing the two demands would require the construction of a *new type of absorbed coping that makes use of the new technology and cooperation*.

Constraints on the development of practices and new artefacts

The present attempts to embody human skills into the physical and conceptual structures of the artefacts appear to detach the navigational skills from the human agent and substitute the system for the navigator in the new distribution of cognition. This kind of development is experienced as a threat to the occupation, within which the skills and knowledge have traditionally been kept secret. One indication of this is the defensive reaction on the part of the state pilots towards a change in the law, which allowed the right of piloting to be granted to qualified members of bridge crews of the ships.

The embodiment and distribution of cognition in the artefacts and among the group of actors potentially enhances the making the actions transparent and facilitates cooperation on the bridge. These changes are necessary in piloting for the integration of different kinds of knowledge and experience in an ad hoc cooperation, and for enabling an adequate monitoring function. For these reasons cooperation has been found to be safety critical in piloting. Cooperation both requires and also facilitates explicit communication of the reasons and intentions of action. Explicitness of communication is an important prerequisite for the development of the new piloting practice because it can enhance the creation of new types of interpretative habits of action within the new technologically-mediated piloting practice.

In the emergence of the historically new way of navigating in piloting there might be a danger of facilitating deterministic approaches in working practice. Such features of practices were labelled as technical rationality (Schön 1988). We maintain that possible means for avoiding technical rationality would be to theorise about the nature of technology and to make explicit the epistemic nature of information delivered by the new technological systems. It should be made clear that the information is useful and meaningful only through the actors' interpretative practices in the context of navigating and steering the ship. In the building up of new meaningful navigational skills, the pilots and the navigators should become aware of the significance of the critical navigational functions of piloting, i.e. of the uniqueness of the ship-sea system and the uncertainty of the hydrodynamic processes, the complexity of the system, and the dynamics of the moving system and the delayed control. Understanding these as reasons for actions while taking into account the situational constraints of action in situated operations would facilitate development of new types of appropriate practices in navigating. Understanding the core-task of piloting could also facilitate insight into the role and proper use of route plans in navigation.

The development of piloting activity would benefit greatly from further research. The aim should be to enhance the understanding of the core task and to derive an elaborated set of criteria for the habits of acting in piloting. The studies should be performed in cooperation with the navigators and pilots. Launching developmental research and actions currently faces organisational obstacles within the activity system of piloting, which also includes the professional pilot organisations and the Finnish Maritime Administration. Therefore, an important final task is to elaborate the situation in piloting and convince the organisations of the benefits of the developmental work within the whole organisation.

7.5 Conclusions of the analysis of the core tasks in studies of normal working situations

The advantage of the Core-Task Analysis methodology in the study of DCU-work lies in its predictive or formative characteristic. By enabling the modeling of the constraints of the domain on the one hand, and by revealing the habitual ways of acting on the other, this method renders a contextual analysis of particular situated courses of action. The studies in the two DCU-domains, anaesthesia and navigation of large ships, were described in this and the previous chapter with the aim of demonstrating that these expectations were realistic.

Insight of the content of daily work

With the aid of several studies both in anaesthesia and navigation we were able, first, to define *what people actually do in their normal daily practice*. Guided by the Core-Task Analysis scheme we conducted analyses and made inferences, which enabled the formulation of further hypotheses concerning the essential content of particular working activities.

Thus, with regard to anaesthesia we defined the sequential structure of anaesthesia in contextual terms relating the phases and tasks to their inherent functional significance for the accomplishment of the generic objectives of anaesthesia, instead of restricting ourselves merely to the structural and sequential description of these phases. The phases could further be decomposed into various sub-tasks. By analogy, we also re-conceptualised the sequential decomposition of navigation into functionally motivated phases with at least tentative decomposition to sub-tasks. In both cases the sequential structure of the task finds its meaning through the motive of the activity, the situational goals and the outcome-critical functions of these tasks. By interrelating these three aspects in both cases not only conceptually but also on the basis of the actual empirical material, we were able to acquire new conceptions of the task.

In the case of anaesthesia we found that the phase of transformation of the physiological state of the patient does not only concern the induction of anaesthetic agents, but it also comprises an equally important intention of constructing knowledge of the state of the patient's physiological functions. The observation of the double function of induction was an empirically and theoretically significant result. The epistemic action is most important for the further control of the anaesthesia process. Correspondingly, in piloting situations the analyses of the task revealed a new content of the task, the active formation of a cooperative navigation team. Success in this action is significant for the completion of the further stages of the navigation, in which the lack of relevant cooperation has been found to be one of the major obstacles to adequate performance, and a threat to the safety of marine transportation.

The evaluation of the core-task orientedness and situative appropriateness of action

Second, we were able to show that *the core task consists of habits of action* that are definable with respect to how and to what degree the agents in their actions *take into account the functionally critical constraints of the particular domain*. The accounts of the actors could be seen to reflect particular orientations towards the object. The orientations represent the personal sense of the object as the goal of the situated action and they are assumed to have a regulating role in action. The personal stance to the object of activity thus expresses itself in the way the constraints of the task are taken into account in action through the utilisation of available tools, in the habits of action. The concrete content of the habits of action is determined through the particular ways of interacting with the environment and the psychological demands that the attaining of the result in the particular domain may set.

The evaluation of the appropriateness of habits in maintaining interaction with the environment is accomplished through determining the interpretativeness or reactiveness of the practices. This evaluation dimension draws on the philosophical idea of Charles Peirce concerning the dynamic of balancing between the state of doubt and the state of belief, which balancing is mediated by a creative abductive relationship towards the world. Abductiveness may be described as a relationship that is qualified by an interpretative and experimental relationship, whereas the lack of abductiveness characterises a relationship that is reactive and recording, a mere mechanical routine (Dewey 1997, Peirce 1998a). This evaluation dimension expresses the level of *situative appropriateness or adaptability* of actions and, thus, connects to the fundamental need for a living system to survive in its environment. At the same time we deal with abductiveness in a contextual way as we connect it to core-task demands and outcome-critical functions and obtain an evaluation of the core-task orientedness of actions. We see that the evaluation dimensions of *core-task orientedness* and *adaptability* replace the dimensions of coherence and situativeness that we used in our earlier studies.

Development of expertise is not a linear result of experience

A third significant result regarding the habits of action was that *differences in habits of action were not found to be a linear result of the accumulation of experience*. In the anaesthesia studies we were able to verify the hypothesis that the decisive features of habits of action, which were first identified among experienced anaesthetists, also characterised the actions of novice practitioners. Furthermore, we were able to verify empirically that the development of the practice tends to take different perspectives according to the orientation of the practitioner. The orientation is either towards a reflective or a confirmative observant expertise. The ability to form conceptual professional knowledge to be incorporated into a personal inference basis and reasons for action – we called this actionable knowledge – was connected to the growth of interpretativeness in action.

Because the development of expertise always takes place within a community of practice, the habits of action and their development necessarily reflect the professional values and practices of the whole community. In the case of anaesthesia it was concluded that the development of a reflective practice, that was considered to meet the demands of the safe and effective care of the patients, is contrasted by other current developmental tendencies in the activity system. These would promote a technically rational and regulated perspective for the future development of the profession and the activity system.

Historical determination of habits

Fourth, the *historical determination of habits* was clearly demonstrated by our results of navigation in piloting situations. The traditionally appropriate and currently still partly functional way of piloting appears to dominate current practice. With regard to the future development of the new habits of piloting we identified the need for balancing between the advantages of the new technology for control and cooperation, and the threat that its adoption appears to create. The threat refers to the possibility of losing the situativeness of the piloting practice and its implicit epistemic insight into the uncertainties of the navigation system which characteristics are well developed in the traditional practices. The development of a historically new form of an interpretative and explicitly cooperative way of piloting is an acute challenge for this profession.

Habit-oriented analysis reveals the internal good of practices

Our final conclusion relates to the core task method itself. The focus in the two previous chapters was to demonstrate the usefulness of the Core-Task Analysis method in revealing the *essential content of a working activity on the basis of careful observations and analyses of normal practices.* The adoption of a formative-habitual approach in the modeling of the task and the creation of a reference for the analysis of actions appeared to promote this aim. Analysis of actions from a habitual point of view orients the investigator to clarify the meaning of actions, and, ultimately, the personal sense of actions to the actors may be inferred as a last phase of the analysis. The modeling of the formative constraints and the generic habits were means to accomplish this difficult task. These notions allow the analysis of action from the point of view of the shared societal meanings that the subjects may take into account in their actions. Analysis of what personal sense these meanings make for individual actors reveals the psychological personal dynamic of the situated construction of actions and the development of practices in the community.

The evaluation of habits of action was based on criteria that may be conceived to reflect the standards of excellence of each studied practice. The criteria were thought concretise the abductive relationship to a continuously changing environment. The *core-task orientedness* portrays contextual coherence of behaviour, and *adaptability* a situational appropriateness of behaviour expressed by the dimension of reactives-interpretativeness. Fulfilling of these standards expresses the achievement the *internal good of the practices*. As MacIntyre has argued the evaluation of the practices is possible on the basis of internal criteria that the members of the community of practice may define, but not on the external criteria of practices (MacIntyre 1984). This theory provides a theoretical background for our attempt to evaluate actions. The interpretation of our evaluation criteria of habits of action in the light of the moral philosophical theory of MacIntyre thus enables a non-subjective and contextual evaluation of the practices. In developing his theory MacIntyre drew from the Aristotelian tradition according to which factual statements and normative statements are of necessity not detached. Thus, for example the concept of “farmer” and “a good farmer” are related, due to the fact that “farmer” is a functional concept that is defined in terms of the purpose or function that a farmer is characteristically expected to fulfil (MacIntyre 1984, p. 58).

In this chapter we demonstrated that *the Core-Task Analysis method also qualifies in the analysis of accidents and incidents* and that it facilitates generic inferences and conclusions from individual courses of actions leading to accidents. The results of such analyses may be compared with other research results of the same working activity. This should promote further learning from accidents and incidents.

CONCLUSIONS

8. Creating reflective expertise in organisations

In this book my interest has been to understand action and sense making in a dynamic, complex and uncertain (DCU) environment. I have introduced the Core-Task Analysis methodology as a means to comprehend the construction of situated actions in particular working contexts and to grasp the development of working practices in the communities of practice. The methodology has emerged through a number of empirical studies. These have been conducted in process control domains, which, due to their particular characteristics, could be considered to exemplify the generic demands that the intensive knowledge-based modern work puts on human action. Consequently, the ways of coping with these demands may be interpreted to refer to the type of expertise required in modern work. The exploitation of the possibility of drawing generally relevant conclusions from human factor studies of process control was thought to require distancing oneself from the prevailing positivist methodology and information processing approach to process control. As a solution the proposed research methodology adopts an ecological point of view. Furthermore, it draws on the epistemic principle that emphasises the role of practice in creating knowledge.

The cultural historical theory of activity and the pragmatist conception of habit provided the theoretical underpinnings for construction of the research methodology to tackle the object of research, the situated action in an activity context. In this concluding chapter I shall reflect on how far we have come in the intended direction. Furthermore, I shall discuss the consequences of our methodical and empirical results for the managerial strategies for developing work in high-reliability organisations.

8.1 The reconstruction of process control as a research object – process control as practice

Process control is usually considered from the perspective of operative managing of the physical, chemical, or physiological phenomena of a particular natural, industrial or transportation etc. process. The operative aspect refers especially to the demands on the operators to stay in the loop in the rather complex dynamics of the on-going process. This assumes that the operators are aware of the state of the process and are ready to act when necessary. This in turn demands judgement and ability of the operator to act under conditions of uncertainty.

The work domain as an object of control and knowing

In cognitive studies on process control, the objects of control are usually man-made systems, within which the underlying natural processes are utilized. These processes are *kept in control using advanced technology*. Due to this, objects become complex, and coping with complexity seems to become the major demand. This demand is connected to mastering the dynamic phenomena of the processes. Possible uncertainties are interpreted as disturbances of the technical realization of the process. Uncertainty is equated with an unanticipated event or disturbance. Disturbance handling, then, is interpreted as that action of the operators, in which they are reacting to the deviation with the aim of stabilising the process. When the process is not disturbed, but is in its normal state, there is no uncertainty. Thus, process control is often described to constitute of 99% of boredom and 1% of horror. The technically created normality of the behaviour of the process represents the generalised knowledge of the underlying phenomena. It is precisely described and also materialised in the technology. Operators' interference is considered necessary mainly with regard to disturbance handling, in the 1% of exceptional time. For the safety's sake, disturbance handling is prescribed as being tackled procedurally. In this framework it is natural to think that the reliability of the process and the epistemic certainty of its phenomena are best achieved by making practice rigorous and controlled.

The conceptualisation of the production process using the above-described dichotomy of the normal and disturbed state appears to be a common practice not only among analysts but also among the operators. Our claim is that this notion frees the analyst, and the operator, from treating the object of control as an *actual epistemic* object. However, should it be approached as such the actor would have to acquire personal knowledge of the object in the particular situation through his, *not only controlling* but also *experimenting and knowledge-creating* operations. This would enable him to control the object, and cope with the ever threatening, even though not always active possibility of disturbance.

Navigation and anaesthesia both provide examples of domains in which the object is not fully mediated through the technological structure. In these domains the connection of the control demands with the incompleteness of the knowledge of the underlying object process is still observable. In order to attain appropriate control of the object in such an environment the theoretically defendable generic need for developing both an operative and an epistemic relationship to the object, and creating an interplay of skill and knowledge in judgement (Dewey 1999, Schön 1988) becomes evident. In order to investigate process control from this perspective it was necessary to develop an empirical method that would be sensitive for both aspects of control, those of operation and of knowledge.

From describing events to understanding of continuous adaptation

In empirical studies the human-environment interaction tends easily to be viewed through particular *events* in the course of this interaction. This point of view has the unfortunate consequence of reproducing the normal-disturbance dichotomy, e.g. in the form of focusing on human error. An event-orientation is a salient solution for the analyst, because he or she is bound to view this interaction from outside. It is difficult to identify the essential dynamics of action without focusing on ruptures in the process. Therefore, an important element in the construction of the object of research as continuous personal practice is the invention of methods that allow a reconstruction of the object of analysis. Instead of looking for events or ruptures, it should be necessary to shift attention to questions and doubts that the agents themselves raise concerning their own action.

When adopting an agent's point of view the major challenge is to give account to the mutual determination of actions both by the subject's intentions and the environmental situational demands. The Core-Task Analysis methodology proposed in this book attempts to cope with this ecological demand on the methodology. The problem is tackled by considering the *contextual* determination of the human-environment interaction. This interaction is considered from two perspectives simultaneously.

First, the human-environment system is placed in its social-historical and material contexts with the aid of the *activity-system* and the functionally oriented *formative* modeling. The modeling of the context of actions is also accomplished in reference to the particular situations, which are elaborated with regard to the functionally significant situational constraints and possibilities for action. Thereby it is possible to define the situation with the aid of the affordances that the environment provides for action, i.e. from a genuinely user-oriented point of view.

Second, the human-environment interaction is comprehended from the intentional, subjective point of view. We exploit the concept of *habit* to express the learned sensitivity of the subject towards the environment. Habits are learned dispositions that enable the identification and use of the situational affordances. Because habits establish such relationships with the environment that enable continuity in the interaction and sustainability of the system habits constitute meanings. Consequently, a method that utilises the concept of habit also provides us with tools to define meanings in the actual texture of actions.

With the help of a semiotic analysis of the action we define *habits of action*, which constitute the psychological-empirical active aspect of habits. Habits of action express a potential for interaction in the particular environment. Habits of action are identified with the aid of a careful analysis of the actual situated courses of action. We distinguish operations that are connected with signs that people have learned to understand as reasons for particular action (von Wright 1998a).

Due to ever-changing situations, which people tackle by means of the abductive functioning of habit, the actualised forms of the interactions with the environment are never equal. Instead, in the interaction the object and its constraints and possibilities are taken into account, and therefore new knowledge of the world can be created. Thus, the habitual sensitivity towards the world creates a *reflective continuity* in action. The habitual conception of action provides a way to study situated action as continuous practical interaction with the environment, as dynamic non-eventfulness (Weick 1987). Reflectiveness is therefore a potential qualification of normal daily action, as well as it may describe action in especially demanding situations.

The identification of whether an action expresses reflectiveness requires that actions are studied both on the level of their actual course and on the level of the habitual dispositions that they manifest. Such an analysis may provide explanations for particular normal or erroneous courses of action, and predict possible further alternatives of performance.

It appears to us that the descriptive concept of heedfulness that was proposed by Weick and Roberts (Weick 2001, Weick & Roberts 1993) to express an attentive attitude towards the working environment in an organisation could be elaborated by our habit-oriented analysis of practice. We propose that heedfulness is such practice that is qualified by a realistic orientation and interpretative habit of action would open up the developmental trajectory of reflective expertise.

Making personal sense of work

The concept of habit appears helpful in clarifying the interactions between the hierarchical levels of activity proposed by Leont'ev. He maintained that these interactions are important for understanding of the psychological dynamism of activity. Concerning the conceptual model of the Core-Task Analysis (Figures 6 and 18) we have proposed that *habit* denotes specifically the societal *meaning* of actions. By his actions the actor expresses what *personal sense* these societal meanings make to him. According to Leont'ev, personal sense expresses the relationship between the motive and the situated goal. This relationship is in the CTA expressed through the concept of *orientation*. In the method the societal meaning is operationalised as the objectives of work and outcome-critical functions that the domain sets forth. The functional constraints of the environment must also make sense to the actor. It becomes evident in the actual operations in which the situational conditions are taken into account. In the Core-Task Analysis *habits of action* are seen to express *personal sense embodied in operations*. Habits of action connect the personal goals of action with the afforded operational conditions. The significance of this relationship for personal action was not elaborated by Leont'ev. However, the proposed interpretation should not contradict his conceptions as he explicitly considered operations as conveying meaning.

Thus, we have used the habit concept for understanding the dynamics of action via the notion of personal sense that is simultaneously manifested in conceptual orientations and corporeal habits of action.

The nature of habits as social and personal dispositions becomes clear in the empirical results. Thus, for example, in the domain of nuclear power production it was observed that there is a strong social pressure for habits of action that facilitate predictability and reliability of system functioning through a precise following of rules and standards. However, in our analysis of the operators' actual coping with difficult disturbances we found that at least some operators' behaviour manifested habits of action in which personal judgement and interpretation were the dominant features. Some other persons' habits of action were found to coincide with the expressed normative habits. We presented reasons that the former habits of action would be situatively more appropriate and, therefore, better promote the aimed long-term outcomes of the production process. With regard to anaesthesia, it became evident that the predominant epistemology of practice in the scientific community of medicine nurtures reactive habits of action, in which the epistemic and interpretative possibilities of the clinical practice are neglected. However, an optional, interpretative habit of action had emerged which was argued to provide a more appropriate way of tackling the core-task demands of anaesthesia. Finally, in the analyses of navigation and piloting we were able to demonstrate the evolution of habits and the historical determination of their internal good. Due to its adaptive strengths, the traditional way of navigating is still today reproduced within the shipping community notwithstanding its weaknesses in meeting the expanding outcome-critical demands of the present navigation activity.

Need for better understanding of distributed cognitive systems

When reflecting the empirical studies presented in this book it becomes evident that understanding and developing process control actions require further work. It would be necessary to analyse empirically the formation of habits within the communities of practice. This would require a longitudinal approach, of which our third study on anaesthetist practice was an example. Such studies would definitely require cooperation with the practising professional community and the organizational management. Another major research task that emerged deals with the development of empirical criteria for the analysis of cooperative habits of action. Cooperation should be studied in the context of the operative practices, not as social skills as such. Via our studies on disturbance handling in NPP operations and the investigation of navigation activities, we have made first steps in this direction.

The technological mediation of working processes was claimed to produce complexity. It was further claimed that uncertainty, another inherent feature of these domains, might appear to be mastered through the very technology. However, increasing technological mediatedness does not mean disappearance of the uncertainty. Uncertainty may only become less and less evident in normal operations. Consequently, the actors should not only be aware of this fact but also be prepared to cope with the technology-induced demands on the conceptual mastery of the object and on the interpretation of the process information. To facilitate a realistic comprehension of the role of technology in the future working processes it would be beneficial to see human cognition from a perspective that acknowledges the societal and physical embeddednes of cognition and focuses on developing practices as distributed cognitive systems (Hollan et al. 2000). This approach emphasises the unity of the human-environment system within which cognition is maintained culturally and distributed between the artefacts, environment and the human actor.

The pragmatist habitual conception of action promotes taking distance from interpreting the process control as a dichotomy of disturbed and normal states. It offers a more accurate conception of uncertainty and provides a means for coping with it. Through emphasising the practical aspect of knowing it draws attention to the actual interaction with the process, and avoids reducing the mediated control of the object to passive receiving of information of the states of the technically mastered process. Practice emerges as a way of coping with uncertainty, as was proposed by Dewey (1999) in his operational conception of knowledge.

Interpreting process control as practice in the above described pragmatist sense does not only open new possibilities to study process control work. Even more, it enables interpretation of the results of process control in a wider perspective of human conduct, to which it may bring some new empirically based insights.

8.2 Interpretative habit of action constitutes reflective expertise

We maintain that our empirical research has contributed to the understanding of human conduct in uncertain environments. Three major results were achieved. The theoretical notion of reflectivity of habits was elaborated empirically in the interpretative habit of action combined with a realistic orientation. Further, we indicated that interpretativeness as a qualification of expertise is not a linear result of the amount of experience. Finally it was suggested that interpretativeness might be learned by facilitating situated attentive engagement with the core task. In the following each of these points will be dealt with.

Realistic orientation and interpretative practice manifest ”reflective habituality”

The idea of the reflectivity of habit is significant for the comprehension of habit as constituting an adaptive means of the human actor in interacting with the environment. This issue was tackled in some recent philosophical studies dealing with the concept of habit (Joas 1996, Kilpinen 2000). Kilpinen introduced the concept of reflective habituality, which provided decisive theoretical support for our habit-centred conception of action and its use in the Core-Task Analysis methodology. The notion of reflective habituality appears to provide an explanatory frame for the differences that were found in the habits of action within the nuclear power plant operators and the anaesthetists. On the basis of a semiotic, habit-centred analysis of the courses of action two basic types of habits of action were identified, which we labelled as the interpretative and the reactive habits of action. These types should be considered to form a dimension on which actual-empirical practices may be projected. Reflective habituality manifests itself in the interpretative habits of action and is connected with a realistic orientation toward the object of work characterised by understanding the particularity and the contingencies of the object of work.

Habits may be conceived from at least three perspectives. These find expression in the everyday use of the concept. First, habit denotes *repetition and regularity* of behaviour. This aspect of habit is by far the most dominant in the everyday but also in a scientific use of the word. Repetition or routine is without doubt important for action because it provides continuity to interaction with the changing world.

However, because it provides continuity, repetition also conveys the particular *meaning* that the interaction has for the subject. This characteristic of habit to express meaning is the second aspect of habit. Habit is a way of being in the world, and may be understood to relate to a personal style, “my way”, or social customs. Important is therefore that what is repeated is the *way* to set oneself in relation to the world in a situation. The "way" conveys the message that needs or should be repeated in a particular situation. It constitutes the reason for repetition. Because the meaning is the reason for repetition, habit is not determined by the situational constraints. Instead, habit may function in a reflective way as a critical and controlling moment in situational action. Thereby the third aspect of habit, its *reflectivity*, emerges. This aspect is typically neglected in the everyday use of the term. The reflective nature of habit was elaborated by Charles Peirce (especially in his last Harvard lecture) as he considered the abductive way of working of habit. This qualification of habit provides generality to human conduct through facilitating interpretation (Peirce 1998a).

We maintain that essential for understanding of habit is to comprehend the connections between these three features of habit. Thus, repetition is the key process of adaptation that a habit facilitates. However, because the habit does not refer to the actual realisation of action, it is the way of being in the world that is repeated. Hence, the changing conditions and their effects on performance may be taken into account in the construction of an act. In this sense the conditions really determine the act. However, at the same time, the conditions constitute a source of doubt and critique and an eventual tuning of actual actions takes place. Even a change of habit may ensue. Therefore reflectivity emerges from repetition. They are not contrary to each other; rather they together form the reflective habituality.

The role of repetition within the concept of reflective habituality demonstrates an interesting similarity to the idea that Ingold presented with regard to the role of imitation in learning in a community of practice (Ingold 2001). According to Ingold, the development of an organism that continues through its whole life originates in the organism by its own actions following what the others do. Copying or imitation is an aspect of a person's life in the world, and it involves repeated tasks and exercises. Ingold claimed further that a process of improvisation always accompanies imitation, which takes place in a particular situation. Improvisation is the source of personal and situational knowledge.

"Copying is imitative, insofar as it takes place under guidance; it is improvisatory, insofar as the knowledge it generates is knowledge that novices discover for themselves. Thus conceived, improvisation – in Bourdieu's terms – is "as remote from creation of unpredictable novelty" as imitation, "a simple mechanical reproduction of the initial conditionings" (Bourdieu 1977, p. 95, Ingold 2001).

These two, imitation and improvisation together constitute *guided rediscovery* (Ingold 2001). Guided rediscovery is the way of developing new knowledge in a novice-expert situation. This conception questions the notion of learning as a process of transmission of information from the expert to the novice. By analogy, repetition as self-imitation in interaction with the world is accompanied by a reflective or experimenting personal act, together forming the reflective habituality through which knowledge is created.

We may conclude that habits express imitation and repetition combined with improvisation and reflection. The extent of reflectiveness may vary in the empirically observable habits of action. In process control the core task consists of judging the state of the process with regard to the outcome-critical constraints and the objectives of the activity. Under these constraints the functional significance of reflectiveness in the interaction with the object of activity becomes more evident than in some other working activities. The interpretative habit of action is the concrete psychological expression of reflective habituality in action. It expresses itself in a practical experimental relationship with the world. Such an experimental relationship was considered as the essential feature of reflective thinking by John Dewey (1997). Hence, we may state that our empirical results provide counter-evidence to the frequent conceptual contrasting of routine habit and reflective thinking. Our results rather support the idea of reflective habituality (Joas 1996, Kilpinen 2000). Reflective habituality may become more or less actualised in the real habits of acting and thinking and it is a qualification of expertise as it facilitates situatively appropriate action.

Non-linear development of interpretative habits of action

The second important finding was that the existence and prevalence of the interpretative habit of action is not a linear result of the amount of experience in the profession. In the study on the clinical practice of anaesthetists we found that when the habits of action of experienced and the novice anaesthetists, were evaluated with criteria adapted to each group's particular professional situation, interpretative and reactive habits of action in both groups could be found.

Earlier we made the observation (Norros 1995) that prominent theories and studies on expertise (Dreyfus & Dreyfus 1985, Hammond 1980) appear to neglect the differences in expertise *within* the experts and novices, respectively, and rather concentrate on factors that distinguish *between* these groups. We suggested, further, that these theories might therefore have difficulties in explaining how the accumulation of experience results in expertise, or when the novice begins to be an expert. Also Sandberg has drawn attention to this restriction in the prominent competence theories (Sandberg 2000).

Our solution to this problem was to demonstrate, by adoption of the habitual conception of action, that there is continuity in action from novice to expert. This conception enabled the distinction between the potential aspect of action on the one hand, and the actual and situated course of action on the other. The continuity in action is identifiable on the habitual level. Habits define the person's stance to the repeating experiences and, thus, they predict a certain trajectory for the further accumulation of skill and knowledge. Usually, when the actual performances of experts and novices are compared, the criteria used refer to the observed actions, or inferred internal operations of realised action. These criteria reflect situational differences between these two groups, typically related to the length of professional practice.

The above reasoning raises the demand to elaborate what is the origin of the different habitual orientations of a person to the world. We are not able to provide a precise answer to this question but claim that it must be a result of the type of interaction that the person has appropriated very early on and through out his life. With reference to the ideas of Uri Bronfenbrenner (1991) the type of responses that one receives from other persons and the environment as reaction to his or her own acts appears to affect the shaping of the development of the relationship to the world. A re-mediation of the relationship may be possible but it requires reflection on the personal sense of actions as e.g. Koski-Jännes has shown in her work with alcoholics (Koski-Jännes 1999).

In our study on anaesthesia we found that those novices who acknowledged uncertainty in the object, i.e. the patient and the anaesthesia process, and in the knowledge concerning these, tended to develop an interpretative habit of action. This practice was qualified by an extensive and experimental use of situated information during the practical operations with the patient. The characteristics of this practice cohere with the ideas of Dewey, who in his writings on experience emphasised that experience emerges out of connecting results with actions that produced them. When a person succeeds in mastering this connection he has learned something (Dewey 1997, Kivinen & Ristelä 2000).

Novices learn their personal practices within the communities of practice, usually in an apprenticeship-type of situation. Therefore, it is probable that the practices of the novices tend towards the prevalent habits of action that converge with the socially defined content of habit. In our study, the proportions of the two observed habits of action were equal in the novice and expert groups, which result could be interpreted as a sign of this tendency. Thanks to the improvisational-reflective aspect of habit, other perspectives of development are also possible.

In a fully-fledged habit there is an intention of creating knowledge during the control of the process, but also for the benefit of later control tasks. The unity of the control and epistemic intentions reflects the unity of repetition and reflection. According to Ingold, both aspects are a result of the *situated attentive engagement,* which is claimed to be a fundamental prerequisite for becoming a skilled practitioner (Ingold 1996, p. 179). This specification of the relationship between the subject and the world expresses the Zen-philosophical idea that for an action to be fully mastered and convincing a *complete presence* in the situation is assumed. This notion provides an energetic complement to the concept of orientation that expresses an epistemic attitude towards the object of activity. We found the concept of situated attentive engagement to be decisive, because it facilitates elaborating how the actual acts become meaningful each time they are repeated. Our interpretation is that the more adequately the psychological core-task demands were met the more reflectiveness there was in the habit of action, because *through the situated attentive engagement with the object – that the interpretativeness assumes – the societal meaning of the object became present in the act as a personally sensible reason for repeating the act.*

The famous Swedish film director Ingmar Bergman identified the idea of complete presence as he drew attention to a distinct difference between excellent actors and the less talented ones. The difference lies in the way the role is repeated every night:

> I long for peace, order, kindness. It is the only way we can approach infinity. It is the only way we can solve mysteries and learn the mechanisms of repetition. Repetition; living, pulsing repetition. The same performance night after night; the same but, yet, reborn. How else can we learn the split-second rhythm of our assigned dialogue, which is so essential to avoid degeneration of the performance into a lifeless routine or an intolerable unruliness? All good actors know the secret intrinsically, the average must learn it, bad actors never learn (Bergman 1987, p. 35) (translation LN).

Thus, we maintain that reflectivity develops and expresses itself in a pre-reflective interaction with the environment and it requires situative attentive engagement with the objective world. This central idea can be traced back to the ideas of Gibson. He proposed that people do not learn to perceive by taking on board mental representations or schemata for organising the raw data of bodily sensation. Rather, learning takes place through a fine-tuning or sensitisation of the entire perceptual system – comprising the brain and peripheral receptor organs and their neural and muscular linkages – to particular features of the environment (Gibson 1979, pp. 246–248, Ingold 2001, Järvilehto 1998a). Michael Polanyi, in his writings about the development of tacit knowledge, also emphasised the role of repetition of meaning for the gaining of experience and knowledge (Polanyi 1974). According to Polanyi useful signs of the environment act as tools that carry meaning. These signs are in a subsidiary position in action but control action and constitute tacit knowledge.

"We may say, more generally, that by the effort by which I concentrate on my chosen plane of operation I succeed in absorbing all the elements of the situation of which I might otherwise be aware in themselves, so that I become aware of them now in terms of the operational results achieved through their use "(Polanyi 1974, p. 61).

Facilitating learning by educating attention

Our results, thirdly, cohere with the idea of Gibson that learning can be facilitated through *educating attention* (Gibson 1979). We were able to demonstrate that articulating relevant concrete features of the young doctors' practices resulted in learning, assuming that, expressed in a realistic orientation, there was a personal insight of the epistemic significance of these practices. In other words the particular practices were seen to be significant for delivering information that could be functional in the further care of the patient. Thus, the young anaesthetists created a personal sense for the interpretative efforts taken. Moreover, a personal construction of concepts of the basic functional physiological principles, labelled actionable knowledge, was required. The practices could be reflected upon in the context of this kind of knowledge. The interpretative habit of action was decisive in the construction of new knowledge because it promoted building up a link between the skill acquired in practice and the formal knowledge. Thus it provided a possibility for efficient learning from experience.

Our results concerning the possibilities for improving learning in practice are tentative. However, it is clear that a precondition for facilitating learning is an insight into where to direct attention. Analysis of practices is needed to infer what features of practices are parts of habits that are appropriate for the attainment of the outcomes of the activity. According to the pragmatist theory, change in action is facilitated through understanding the signified object as the reason for action, not only through becoming aware of the interpretant, the act itself. In his article on pragmatism Peirce emphasised that the interpretant is much more readily intelligible than the object since it includes all that the sign itself expresses. The sign does not express but indicates the object and the relationship must be comprehended (Peirce 1998b).

When the concrete criteria for habits of action were defined as a result of the Core-Task Analysis, the aim was to make the objects more intelligible. The objects were interpreted as possible reasons. In the determination of habits of action they were compared with what the actors actually understood as an object, as effective reasons. Reflecting on one's own actions in the light of their meaning opens up the perspective for learning. The creation of a new meaning is an emotionally significant moment, in which the whole action is viewed, in a new light (Koski-Jännes 1999).

I experienced the strength of the moment of acquiring an insight in one's own action when investigating an air traffic incident that had occurred in a peripheral small airport. In this incident an aeroplane almost landed on a vehicle and two maintenance men who were repairing the runway lights. In the interviews the air traffic controller who had been working in the tower when the incident occurred became suddenly very emotionally involved and uttered that "I have got into the habit of giving landing permission before I verify that the runway is clear". It was evident that in that moment the person involved gained personal insight into the significance of the well known basic safety critical function of verifying the runway to be clear, and into the fact that this objective was not maintained as a reason in his actual performance. Such wearing out of critical functions as reasons for action may take place in working situations, in which the significance of the critical functions is not regularly evident. In this case, the low traffic volume could explain the flattening of the expertise and the fact that runway was usually clear.

In a recent paper, Hollnagel analysed different models of human action and their relevance in explaining accidental events. He called for understanding actions as practices that have evolved via a process of local optimisation. People try to be sufficiently thorough but avoid unnecessary effort (Hollnagel 2002). We see that our results are compatible with the generic trade-off principle but they shed further light to psychological dynamics of adaptation by the notion of personal sense of actions.

Thus, awareness of the reasons for actions should be facilitated through reflection on the core task. However, because practices develop in communities of practice the decisive prerequisites for change in practices is a common effort of these communities.

Reflective and confirmative expertise

The results presented in this book allow an articulation of our conception of expertise. This conception is not an administrative definition, in which the qualifications would be specified and the length of experience in the task be considered central. Instead, a habit-centred definition of expertise emerges. As the definition of the practices focuses on identifying the internal goods of the practice our conception of expertise connects between the technical skills and the ethos of a practice, i.e. with the virtues of the practitioner that promote the well-being of the whole community of practice. Drawing from MacIntyre we must accept as necessary components of any practice not only its internal goods and the standards of excellence but also the virtues of justice, courage and honesty (MacIntyre 1984).

In the referred empirical studies the focus of analysis was the construction of situated action. The results indicated that in a dynamic, complex and uncertain environment, human interaction with the world is characterised by two intertwined aspects of action, repetition and reflection. These aspects were found to be embedded in habits that carry on the continuous interaction between the environment and the person. Habits are adopted in social connections and they express shared meanings. At the same time, however, habits take the form of a personal relationship to the environment and personal sense of the goals of action.

We understand *expertise to denote the way a person handles the interplay between the social determination of the object of activity and its internal goods as they are reflected in the societally meaningful habits, and his or her responsibility personally to reconsider the conceptualisation and the significance of these objects of activity and the internal good.* The responsibility for questioning the habits is related to ability to exploit the interpretative potentials of habits. *Reflectivity* in action can therefore be seen as *confidence with ones own personal possibilities*, and as respect of one's own *personal perspective and position in the world* to be a *means to become aware of the societal determination of the concepts and espoused meanings concerning the world.*

Reflectivity in action enables the construction and re-construction of the object of activity and the internal goods of practices. Acceptance of another person's equal possibilities and worth is of course the necessary condition for communication about shared objects.

Expertise can be interpreted as expressing the actor's own balancing between repetition and reflection in his/her relationship to world. The differences in expertise thus become crystallised in the practical ways of utilising the possibilities of the situation in the construction of the situated object of action. *Interpretativeness of habit of action enables the reflectivity of situated action and creates the possibility for new knowledge in particular singular situations.* Thus, the more interpretatively the actual possibilities of the situations are attended the more reflective the action may become, and the more critical in relation to the societally acquired schemata of perception and conceptions the actor may become. The interpretative habits of action create a trajectory of *reflective expertise*. Without interpretative features actions tend to be *reactive* and a trajectory of a *confirmative expertise* emerges.

Our conception of reflective expertise is in concert with that of Bourdieu, in which the awareness of the societal determination of our conceptions is seen as the essence of reflectivity (Bourdieu & Waquant 1992). It also coheres with Donald Schön's notion of a reflective practice as it emphasises the epistemic significance of operative skills in making sense of the world (Schön 1988).

The trajectory of reflective expertise must be explicitly promoted in modern life and work because the increase of information and formalised knowledge connected to the advancement of technical possibilities of copying and transforming information may easily create an illusion of knowledge separated from skill and practical operations. Without active personal involvement a *confirmative expertise* easily emerges. Thus, the proper understanding of the subjectivity of knowledge and local embeddedness of the subject as important prerequisites for learning and development of expertise must be facilitated. A firm personal relationship to the world is the more important the more we make use of the developments of communication and information technology that extensively shapes the local work and living environment, increases the amount of information and makes the world more global. Consequently, new challenges for management emerge in organisations with regard to facilitating the development of reflective expertise and for promoting design of artefacts that support such development.

8.3 Optional organisational strategies in coping with DCU-environments

Sociotechnical systems in dynamic, complex and uncertain (DCU) environments usually involve a high concentration of energy and considerable economical stakes. Uncontrolled operations in these environments may have profound effects on people's health or cause severe harm to the environment or great economical losses. Under these circumstances the quest for reliability of the functioning of the systems is of great importance. Reliability means that the functioning of the system does not deviate excessively from designed operations and that the intended outcome is achieved. Safety and economical efficiency are consequences of reliable functioning of the system.

Two basic strategies: standardisation and promotion of adaptation

Standardisation of human performance and the technical functioning of the system are the usual strategy of maintaining reliability in a complex system. Thus, for example a complete automation of particular functions of the system is indispensable in circumstances in which, for example, the boundaries of the human natural capabilities for precision or speed of actions are exceeded, or human perceptual possibilities are insufficient. Furthermore, there are situations in which demands on specific human capabilities are very high, e.g. on spatial three-dimensional imagining in air traffic control. In such cases the reliability of the functions of the system may be promoted by careful selection of personnel on the basis of ability testing, which aids in ensuring fulfilment of the performance standards. Norms and procedures are further examples of standardisation that create reliability and predictability in complex systems (Norros & Nuutinen 2002).

Despite their importance, the standardisation measures do not provide sufficient insurance for reliability in open systems such as acting in DCU-environments. Under the constraints set by the context-conditioned variability typical of these environments, the achievement of the outcome or maintaining the functions in the designed boundaries of safety or economy require adaptation with regard both to the human actions and to the technology. Unexpected problems must be settled locally but with an awareness of the whole. Procedures, norms, or quality systems are exploited to maintain a holistic perspective. However, mere compliance with the standards is not sufficient in DCU-environments. It is necessary that the actors have understood the critical functional principles behind the standards as reasons for action, i.e. their connection to the core task, and that they are able to judge features of particular situations with reference to the core-task. Such a core-task informed compliance with the rules is part of the core task of DCU-work because it enhances the shared awareness of the situation and the predictability of the system. Understanding the functionality of the rules also entails that rules are taken into account under all circumstances, even when the functional demand is latent. These features are appreciated in the organisational orientation that could be labelled the *strategy for adaptation*. It is based on facilitating *reflective expertise* in the organisation.

Neither the achievement of the reliability of the system, nor its actual, material or ideal, *products* are as such the true objectives for the human action. Rather, the objective is the maintenance of such an interaction with the environment that provides *new possibilities* for action and continuity of life (Järvilehto 1998a). The extent of the realisation of this potential constitutes the final criterion for the evaluation of the appropriateness of the functioning of a system, and for the adequacy of actions. This distinction made by Järvilehto between the actual products and the new possibilities of activity may be linked with the distinction of MacIntyre between the external and internal goods of practices. The external goods may be seen to relate to the instrumental value of the products, whereas the internal goods are those that associate with the new possibilities for action and the promotion of well-being and life (MacIntyre 1984).

Measuring the realisation of the possibilities assumes understanding of the internal goods of practices including the standards of excellence and the necessary human virtues. This is, of course, much more difficult than verifying the reliability of producing the defined end products. Realisation of the potentials can only be evaluated within the activity itself by using criteria that define the internal good of the practices and culture (MacIntyre 1984). Observing what people have adopted as orienting goals for their situated actions in work, and what values they express in their intercourse and culture, and relating these to the history and the future trajectories of the activity in the society, are concrete measures for the analysis.

Above, we distinguished two strategies for the management of DCU-environments, the standardisation strategy and the strategy for adaptation. We also denoted that the strategy for adaptation is realised by developing reflective expertise and by focusing not only on the products but also on the possibilities of activity.

The representation of the strategies in this idealised and dichotomous way is, of course, not very realistic. The strategies do not appear in pure forms because both have advantages that are significant in practice. Perrow showed that there is a dilemma between the simultaneous needs for centralisation and distributed decision-making in the maintenance of reliability in tightly-coupled and complex systems (Perrow 1984). We maintain that the conflicting organisational demands may be balanced by putting standardisation in the service of adaptation. In this way it could also be possible to redefine and develop existing standards. Realising this option would assume that the organisation is capable of facilitating the creation of personal meaning for compliance with the prescriptions and rules. The organisation should also promote professional judgement in the use of the prescriptions, in one world, it should facilitate reflective expertise and focus on the possibilities of the activity. The standardisation strategy is insufficient as such because it only refers to the defined products and to the external good of practice.

Search for an appropriate managerial orientation in DCU-work

The organisation is an activity system and thus it is defined through its object and outcome. These structure also the manager's actions. Moreover, the managers have a role to interact with the societal and market environment of their organisation. This interaction takes place through the outcomes and they define the position of the company and its identity in the market. Therefore, the manager's insight into the object and outcomes of the activity system is decisive.

The managers face a difficult demand in the maintenance of attention on the object and objectives of the activity. We see two central reasons for this. The first one links with the way of understanding the outcomes of activity. As we indicated above, the outcomes do not reduce to the material products but also entail the possibilities for further interaction. It may be claimed that when dealing with the market the manager may *focus too much on* the products of the company and the *external good* that they may provide. However, this is not a sufficient managerial orientation because the more far-reaching development of the activity of the organisation also assumes focusing on the internal good of those practices that realise the developmental possibilities.

The other reason is that the managers' interaction with the object of the activity takes place in a *mediated* way through the outcomes, of which the managers have mainly indirect information. The managers' *perceptions of the object* of production are mediated by the diverse information of the outcomes provided via different information channels. The information concern typically the material products, including the reliability of production and the resulting quality, efficiency, economy, or safety of the system. Surveys of personnel job satisfaction and the like may also be available. The overview that the managers may acquire of the outcomes and of the performance of the organisation requires interpretation of this information. This may be reasonably easy if the interpretation refers to the material products, the indicators of which may be summarised in figures, graphs and tables. However, the more profound managerial task, a core task, is to judge what these indications concerning the products tell about the organisation's potential to create new possibilities in the organisation, and in the society, including the market.

When attempting to understand managerial activity from a core-task point of view it is necessary to refrain from viewing management as if managers had a top-down perspective on the organisation. Rather, we would like to conceive managing locally from the point of view of situated action. From this perspective the managers are in a relationship with the object and with the market through the *outcomes of activity,* of which they only have *indirect information.* Their *specific task is to orient towards the new possibilities that the products enable.* The manager should in his practices be aware that the outcomes *do not reduce to the external goods* even though they themselves *do not directly have access to the internal goods that provide the possibilities.*

The personnel of an organisation are extremely sensitive to inadequacies of the management in identifying the possibilities and to the neglectance of the internal goods that are needed for its realisation. Experts are insulted by such managerial ideas that convey the message that standards or machines could replace practices (Norros & Nuutinen 2002), because they implicitly know that it is impossible to achieve the internal goods by these means. Such managerial strategy would indicate an action that operates directly on the results and external goods not on the possibilities of the activity. Such an orientation may result in a reduction of motivation and commitment among the personnel, and, of course, the problems are accentuated the more and the higher level of expertise is required by the work in an organisation. Promoting survival of an activity system by creating potentials for the system requires diagnosis of what can be achieved as goals of action within an activity system without directly influencing the goal achievement itself. Therefore the managers must not only perceive but also *act in a mediated way*.

What does the analysis of practices tell about organisations

Enhancing *reliability through standardisation* appears as the dominant strategy in operating organisations. This strategy is directed to intensifying the *production of results and facilitate external good e.g. increase output and reduced costs,* but it is questionable how well this strategy succeeds in creating new *possibilities* for action.

Thus, for example in medical care this prevailing strategy leaves unsolved the pressing problems among the personnel to be able to maintain professional performance and attitudes under conditions of increasing haste. Nor does the strategy take into account the frequently expressed complaints of the patients of being treated as medical cases but not as individuals who need medical care. *Orientating adequately on the object, the patient,* not only in the operating theatres and clinics but also *in the management of operations,* would require taking into account the individual patient's identity and the idiosyncratic nature of his reactions. This would open up a different strategic perspective that would not only account for each patient's justified wish to be treated professionally as an individual but, moreover, would better meet the functional constraints on the whole system. It also would ease the situation of the personnel by strengthening focusing on the core task of medical care. The difficulties experienced by management of medical systems in adopting a mediated mastering of the object and orienting towards the possibilities of the activity, instead directly to the material results, have even deeper grounds. They may be seen to reflect the difficulty to overcome the objectivistic epistemology of practice in medicine that does not acknowledge the creative value of practice and its strength as a tool in coping with uncertainties in the system.

The studies in navigation also provided examples of the principle difficulties in defining an appropriate managerial orientation in DCU-organisations with high safety requirements. Piloting has throughout its history in Finland developed in a spontaneous way as a tacit practice. Today there are evident safety-related needs for creating better resources for the accomplishment of an appropriate level of safety and efficiency of this activity. The providing of these prerequisites for navigation and piloting is the responsibility of the maritime administration. In cooperation with the international maritime organisations the Finnish administration has developed a reasonable normative basis for regulating the activity, and it has also prepared updated general guidelines for the actual implementation of the piloting task to meet the requirements of the recent new legislation regarding piloting. The deliberate strategy is that safety is improved through normative control but that the established norms should not be too detailed. This appears to be a rational approach of the central administration, but from it follows that the responsibility for the application of the norms is addressed to the regional administration. The latter delegates the task further to the pilots acting in the actual situations on the bridge. Hence, the present way of managing piloting activity relies too heavily on the spontaneous development of the actions and reacting to problems.

While it is not acceptable that individual pilots are made responsible for system accidents there is a need of creating a mediating link between the administrative norms and the actual practice. The attempts to enhance understanding and explication of the concrete constraints of the domain, for example the constraints of the routes on piloting practices and the need for cooperation on the bridge, have become opposed by the maritime administration. These reactions reveal the crucial problem. The suggestions are interpreted in the administration as demands for more exact rules of how the pilots should behave in piloting situations. Using the terminology of Vicente (1999) the suggestions are read in the administration from an event-oriented and prescriptive-descriptive perspective. The intention however is, to define the problems in formative-habitual terms. Such an approach could promote practical measures for improving expertise and prevention of accidents. Thus, we may also in this case conclude that the problem lies in the difficulty of adopting a mediated way of managing and of orienting to the possibilities and requirements, rather than directly to the results that may be prescriptively controlled. We may even say that the demand for a mediated management is a central challenge of the work of regulatory authorities in general (Reiman & Norros 2002).

On the basis of the experience of the analysis of the sharp-end actions we may infer that standardisation and normative prescription of practices appear to be a salient strategy in the DCU-organisations, even though expertise is in general valued in these organisations. Hence, it may be hypothesized that *expertise is perceived in confirmative* but *not in reflective* terms. The object and outcomes of activity are viewed through the material products and the maintenance of reliable production that express the external good of practice, not as internal good of practice and the possibilities for the activity to survive and develop.

CTA is a tool for enhancing developmental possibilities in work and to open up the trajectory of reflective expertise

The practical usefulness of the Core-Task Analysis is expected to lie in its ecological orientation and contextual strength. Via modeling the environmental affordances and habits, and making explicit the personal sense of action, the method results in explicating the construction of actions. By this means the method avoids the mere illustration of action and, instead, opens a way of explaining the psychological and social dynamics of the development of practices. CTA should be accomplished in cooperation with the personnel. Reflection of work practices in concrete domain-specific terms may have a catalytic influence on the development of practices. Due to focusing on the meaning of work and the personal sense of actions the method also provides a practical possibility to influence organisational culture.

My reasons for analysing work in DCU-environments are finally very practice-oriented. As a research scientist at the Technical Research Centre of Finland I aimed to provide possibilities for developing technology in the service of human values. The construction of the Core-Task Analysis methodology emerged from urges of sharing this human-centred objective with engineers and from seeking an appropriate empirical research approach to realise this aim. The CTA-methodology should serve as a communicative tool in the interaction between designers, operating personnel, management, administrators and the regulatory authorities.

The CTA methodology focuses on the specific courses of action and conceptions concerning work as attentively as possible, with the intent of understanding their activity-system bound psychological significance and logic. Due to the chosen vocabulary, the method should allow conceiving invariances of human conduct. This feature facilitates prediction and, hence, provides good prospects for implementing the method as a tool in the development of work and organisations. There are already some examples of development applications of the Core-Task Analysis that lead me to believe that we have succeeded to provide some aid to people, who in their daily work face the difficult demands of making sense in dynamic, complex and uncertain environments.

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Acting under uncertainty

The core-task analysis in ecological study of work

Abstract

This book describes the emergence of a new method, the Core-Task Analysis (CTA), to analyse complex work in risky environments. The notion “core-task” denotes the objectives and the outcome-critical content of work, which should be taken into account by the actors in everyday task performance. The orientation to the core task characterises work practices and culture.

CTA adopts a systemic notion of human activity. Situated actions are conceived from an ecological, human-environment interaction perspective. The CTA methodology integrates several theoretical approaches. It exploits ideas of the cultural-historical theory of activity and the functionally oriented cognitive task analysis tradition, and it also borrows the pragmatist concept of habit for the analysis of practice. These approaches share a systemic notion of human activity and conceive action from an ecological, human-environment interaction perspective. Explaining actions from the point of view of their meanings characterises these approaches and the CTA-methodology. The CTA can be used in analysis, evaluation and development of work practices and culture, and it provides a framework for interdisciplinary studies of high-technology work.

The method was developed in studies of work in four technologically highly mediated work domains. These are flexible manufacturing, nuclear power plant operations, anaesthesia and navigation of large ships. Furthermore, it reports empirical results concerning the nature of decision making and action under dynamic, complex and uncertain environments, and comprehends habits that might explain the observed differences in actual situational courses of action. The interpretativeness or reactiveness of habits of action is the central dimension that characterises the situative appropriateness of actions, while the core-task orientation defines the coherence of actions. The book also provides evidence of the deficiency of the notion of a linear development of expertise as a function of experience. It is argued that, rather, depending of peoples' orientation to work and habits of action, at least two different development perspectives emerge, which we labelled the trajectory of reflective expertise and that of confirmative expertise. In the final chapter the method is discussed in the context of the pragmatist conceptions of adaptive behaviour and learning. The book winds up by introducing preliminary thoughts of the use of the Core-task Analysis as a tool in managing high-reliability organisations.

Keywords
risky environments, complex work, activity theory, habit of action, naturalistic decision-making, process control, high-reliability organisation, anaesthesia, flexible operations, nuclear safety, maritime safety

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This book describes the emergence of the method in empirical studies of work in four technologically highly mediated work domains: flexible manufacturing, nuclear power plant operations, anaesthesia and the navigation of large ships. The book may raise interest among research scientists and students of work and organisational psychology, cognitive engineering, and anthropology. Designers and usability experts, as well as managers may also find the book useful.

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