Designing Artifacts for context awareness

Mikael Wiberg & Charlotte Olsson
mwiberg@informatik.umu.se, colsson@informatik.umu.se
Dept. of Informatics, Umeå university, Sweden

Abstract

To design support for distributed cognition is tough. A big amount of this type of systems have been designed during the years and a great number of them have failed in order to fulfill the purpose of supporting people to distribute the cognition. One reason for this may be the lack of support for the design process.

In this article we argue that it exists a lack of theoretical framework to support these processes. We therefore try to examine two existing frameworks; Activity Theory and Distributed Cognition, in order to come up with some conclusions if, and in that case how, these two can be supportive. We also discuss likely differences in results between the two frameworks. We do this by examine the two frameworks and then we apply them to a case; an information system at a department on a hospital.

We show upon the similarities and differences in design results and make a discussion. We finally ask ourselves whether the theories were a support for us in the design process or if an awareness of the approaches of them was enough to make a, sort of more intuitive design. If so, the theoretical frameworks, in this case, and the trouble using them, were in vain.

Introduction

This paper elaborates on how to design artifacts for distributed cognition**.** As a point of departure we argue that there is a lack of theoretical frameworks to support and inform the process and the product of design.

To come up with such a framework, we start by discussing two theoretical frameworks for grasping and analyzing contexts. The two frameworks discussed are 1) Activity Theory, or more Activity Checklist, and 2) Distributed Cognition. After these presentations we consider a case, an information system for supporting nurses in their job at a hospital, and use the two frameworks for suggesting a new design. The paper ends with a discussion of the appropriateness of the frameworks to support and inform the process of design of artifacts for Distributed cognition.

Related work

To put this paper into its proper research context we relate it to previous work, practical as well as theoretical. Kaptelinin & Nardi (1997) argue around the Checklist and it's advantages concerning design and evaluation of information systems. Their work in this article may be seen as one of the first sources related to the Checklist.

Distributed Cognition has been used in CSCW for quite a long time. One example of how it is used is done by Rogers et al. (1998), where they show on how they used the theory for

evaluation and re-design of an information system used in a collaborative setting, a telephone helpline. They point out in this article the relevance of using D-cog analysis to identify redundancy in use of IT-artifacts and breakdowns in communication.

To point out some sources, considering cases, analyzes and design suggestions near ours, the design of "Active Badges", done by MIT is worth mentioning. The active badges sends out information concerning the location of the person wearing the badge.

A similar artifact developed by MIT is the Meme Tag, a badge used to support communication between people. They design badges for context awareness, in that the people passing by a person wearing one of those badges exchange information interactively with their own badges. One more function of the badges is that it displays information of the owner to the person passing by. This technology had the purpose of "breaking the ice" in settings of people who did not know each other, for instance in conferences. However, this application does not give any information about where it is located. (Borovoy, et. al, 1998 pp.159 ff).

The Victoria Institute in Gothenburg has done some work aiming at designing support for context awareness. The 'humming bird' showed at CSCW ´98 is a modified Gameboy with an attached radio transceiver developed to detect and display on the display when someone is in the near context wearing a similar hummingbird (Holmqvist, 1998).

More related work from the Victoria Institute, shows upon a support for mobile collaborators, called NewsPilot. They focus on how dissemination and filtering of information can be connected to the users' mobility. (Dahlberg et al ,1999)

Another artifact developed from the idea of context awareness is the 'Dynamic To-do List' (Bergqvist et. al). The basis technology is the same as the hummingbird, although implemented on a Palm III from 3com. The application uses the idea of nearby persons sensitive information displaying and are applying that idea on the traditional to-do list, thus making it possible to range the things to do automatically due to the persons available in the present context.

Analytical framework

Nardi (1992) describes Activity Theory as the richest framework for studies of context, (among frameworks such as Distributed Cognition and Situated Action). The main reason for this, he claims, lies in its strength concerning comprehensiveness and engagement with difficult issues of consciousness, intentionally and history (Nardi, 1992:358).

Activity Theory seems to be increasingly applied by CSCW researchers as a theoretical foundation for their work. The theory has several historical sources, ranging from classical German philosophy to the writings of Marx, as well as the work of Vygotski, Leontev and Luria in the Soviet Union in the beginning of this century (Kuutti 1994, pp. 51). During the last couple of years the theory has been developed further by, amongst others, Yrjö Engeström.

Hutchins can be seen as the father of an alternative approach to grasp context. An approach focusing on how cognition is distributed between human beings and artifacts, (e.g. distributed cognition). Just as Activity Theory the framework of Distributed Cognition provides a theoretical and methodological framework for analyzing and explaining a variety of contexts. These include one person interacting with external representations to socially distributed systems at large (e.g. organizations). Distributed Cognition also, like the framework of Activity Theory, provides us with a level of description that can be informative when considering the design and deployment of new co-operative technologies. It also provides a level of description that focuses

on the computational and representational properties of artifacts and how they are co-ordinated in distributed work and, just as Activity Theory it highlight mechanisms that are crucial to CSCW and also the bottleneck that other methods may overlook.

Activity Theory

Activity Theory, as described by Kuutti (Kuutti , 1994), is primarily concerned with human activities, such as work. An activity is an action directed towards an object, which is transformed by a subject, i.e. a human actor, using one or several tools, into an outcome. This is assumed to take place in a community, i.e., among subjects sharing the same object. The three parts of an activity, i.e., subject, object and community, which together produce the outcome, are related to each others through so called *mediators* (Kuutti and Arvonen 1992, pp. 235 - 236).

- Tool mediates the relationships between the subject and the object. For example, the hammer mediates the relationship between the craft person and the artifact she creates.
- The relationships between the subject and the community are *mediated* by rules. For example, institutionalized practice, culture, formal routines, laws, and so on regulates the relationship between the individual's efforts in an organization.
- The division of labor mediates the relationships between the object and the community. For example, the division of labor mediates the relationship between the car produced at Volvo and the work force, e.g., work groups, roles, and shifts.

  The above items, when put together, form "the basic structure of an activity" (Kuutti 1994, p. 54). This is visualized in the figure 1.

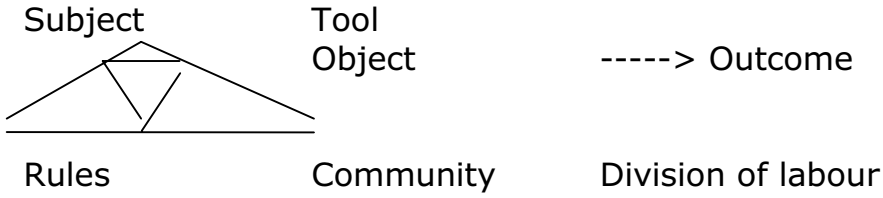


Figure 1: The basic structure of an activity (Cole & Engeström in Salomon, 1991)

(For a summary in eight points of the cultural-historical conception of the basic structure of human activity see Cole & Engeström in Salomon, 1993 page 9).

A disadvantage of the framework however is its rather abstract and complex construction. To enrich the theory in a more concrete manner, Kaptelinin & Nardi (1997) have developed the Activity checklist. The purpose of that development was to provide a concrete framework for evaluation and design of artifacts by starting of from the basic principles of Activity Theory.

This section will aim at give a somewhat brief overview of those principles and the following section will concentrate more upon the details of the Activity checklist as described by Kaptelinin & Nardi.

Activity Theory takes into account social, cultural, historical and psychological aspects of human activities. By doing that, that idea is to give a rich understanding of human beings, their goals and motives, in their natural environment. As described by Kaptelinin & Nardi, two ideas can be said to underlie the whole theory. First of all, *"the human mind emerges, exists, and can only be understood within the context of human interaction with the world"* and second, *"this*

interaction, that is activity, is socially and culturally determined" (Kaptelinin & Nardi, 1997:2).

The unit of analysis in Activity Theory is the Activity. Kaptelinin & Nardi describe the basic elements to consist of three things, (1) a subject, an individual or a group), (2) a motive or an object, and (3) socio-cultural rules (Kaptelinin & Nardi, 1997, p. 2).

> "In Activity Theory the unit of analysis is an activity. Leont'ev, one of the chief architects of Activity Theory, describes an activity as being composed of subject, object, actions, and operations (1974). A subject is a person or a group engaged in an Activity. An object (in the sense of "objective") is held by the subject and motivates activity, giving it a specific direction. "Behind the object," he writes, "there always stands a need or a desire, to which [the activity] always answers."."(Kaptelinin & Nardi, 1997, p. 2).

The Activity Theory consists of five principles, together forming a general conceptual tool or framework for context analysis. The principles are one by one; object-orientedness, hierarchical structure of activity, internalization - externalization, tool mediation, and development. Those five will be further described below:

1. Object-orientedness

The first principle constituting the framework tells us that every activity is directed to an existing object. According to Activity Theory, human activity can be directed to two kinds of objects; (1) to human beings and (2) things.

> "The notion of an object is not limited in Activity Theory to the physical...Social and culturally determined properties are also properties that can be studied with objective methods." (Kaptelinin & Nardi, 1997, p. 2).

2. Hierarchical structure of activity

The second principal, hierarchical structure of activity, describes that activities can be organized into three different hierarchical levels; (1) activities, (2) actions, and (3) operations. The relationship between them is that activities correspond to motives, i.e. top-level goals. Those motives are grounded on some need or desire. Actions are carried out to fulfil the motives. While actions and their goals are conscious, people do not have to be consciously aware of their motives. Actions are driven or pulled by goals. These goals can be broken down into lower level goals, i.e. subgoals.

> "Actions are goal-directed processes that must be undertaken to fulfil the object. They are conscious (because one holds a goal in mind), and different actions may be undertaken to meet the same goal." (Kaptelinin & Nardi, 1997, p. 2).

Activity Theory describes operations as the lowest hierarchical level of an activity. According to Activity Theory an action becomes an operation when it is performed automatically and unconsciously. Operations do not correspond to any conscious goal as action does. Instead, operations react on the conditions. In case of changed conditions a break down can occur and the operation can be transformed back into an action.

3. Internalisation - externalisation

The third principle is the internalization and externalization of activities. As Kaptelinin & Nardi say, internalization is a transformation of external activities into internal ones. The transformation can involve making routine work explicit, i.e. an externalization or learn to do something without

explicit thinking about the specific details of the activity, i.e. internalization. However, as the authors claims;

> "internal activities cannot be understood if they are analyzed separately, in isolation from external activities, because it is the constant transformation between external and internal that is the very basis of human cognition and activity." (Kaptelinin & Nardi, 1997, p. 2).

4. Tool mediation

The fourth principle is mediation. As Activity Theory claims, the tool surrounding us mediates activity. The tool refers to tools in the broad sense of including both external (like computers, calculators, etc.) and internal ones (like concepts, laws, logic, etc.). The principle of tool mediation plays a central role in the Activity Theory. According to Activity Theory artifacts such as information technology, signs, etc. mediate activity.

> "tools shape the way human beings interact with reality. Shaping external activities results in shaping internal ones...tools usually reflect the experience of other people who tried to solve similar problems before and invented/modified the tool to make it more efficient and useful." (Kaptelinin & Nardi, 1997, p. 3).

As Kaptelinin & Nardi (1997) claims, artifacts carry with them a particular culture and history and are persistent structures that stretch across activities through time and space.

5. Development

The fifth and last principle is development. Looking back on the description of the forth principal it is of great importance to consider and understand how a phenomena has developed over time into its existing form. The framework makes it clear that tools are not just constructed to solve a problem. Rather they are carrying with them a history and are themselves a result of transformations, historical as well as cultural and social.

> "Activity Theory sees all practice as being reformed and shaped by historical development." (Kaptelinin & Nardi, 1997, p. 3).

These different principles should not be seen as isolated ideas but rather as an integrated system. The fundamental idea and purpose of the principles is to provide an opportunity to structure and orient thought and research.

However, as mentioned before, the principles may appear somewhat abstract. So, in order to make the Activity Theory more useful, Kaptelinin & Nardi (1997) developed the Activity checklist.

> "Activity Checklist- concretizes the conceptual system of Activity Theory for the specific tasks of design and evaluation." (Kaptelinin & Nardi, 1997, p. 3).

The Activity checklist

The Activity checklist is an artifact developed by Kaptelinin & Nardi (1997) intended to be used in the early phases of design or evaluation of existing systems. The main purpose of the checklist is to help identify the most critical issues involved in evaluation and design. The Activity checklist provides the right questions to raise in order to capture and structure a complex context.

> "The Activity Checklist is intended to elucidate the most important contextual factors of human-

> computer interaction. It is a guide to the specific areas that a researcher or a practitioner should be paying attention to when trying to understand the context in which a tool will be or is used." (Kaptelinin & Nardi, 1997, p. 3).

The checklist also puts a heavy emphasis on tool mediation. That principle of Activity Theory is then systematically combined with the other four basic principles.

Kaptelinin & Nardi (1997) present both evaluation and design versions of the checklist. The checklists are constructed after the basic perspectives of Activity Theory, each offering a list of think-about-items. Those items form lists of importance when approaching a design or evaluation process.

The four perspectives of the checklist are; (1) means and ends, (2) social and physical aspects of the environment, (3) learning, cognition and articulation and, (4) development.

Distributed Cognition

Before considering the case of the hospital and start to analyze it from the perspective of Activity Theory and Activity checklist the second framework for context analysis will be presented and discussed down below.

Distributed Cognition is an approach to study cognition that goes beyond the skin of the individual. It focuses on the distributed nature of cognitive phenomena across individuals, artifacts and internal and external representations. In particular, the analysis of complex socially distributed work activities of which a diversity of technological artifacts and other tools are an indispensable part.(Rogers & Halverson, 1998)

The unit of analysis for a Distributed Cognition analysis is distributed activities among human beings and artifacts. It thus describes distributed activities in terms of socially distributed representational states, cognitively distributed representational states and technological distributed representational states. (Rogers & Halverson, 1998)

The main idea has been to lift out the central idea underlying cognitive psychology of sensory inputs, representations and processes going on inside a persons head and instead apply it in a distributed context, e.g. to describe the same thing as going on beyond the single individual. Distributed Cognition then opens up the possibility to study cognition beyond the skin of the individual as well as it open up the possibility to take artifacts and physical representations into consideration. (Rogers & Halverson, 1998)

The framework of Distributed Cognition is a theory of the "in between", that is, what happens outside peoples heads, beyond their thoughts. It focusing on things and events taking place "in between" such as conversations, use of artifacts and the artifacts themselves, interaction between humans as well as between humans and artifacts.

It also put a strong emphasis on representations (rulebooks, etc.). Distributed Cognition deals with what can be seen as observable cognition:

> "with systems of socially distributed cognition we can step inside the cognitive system and while some underlying processes (inside people's heads) remain obscured, a great deal of the internal organization and operation of the system is directly observable" (Hutchins, 1995, p. 125).

Distributed Cognition puts a strong emphasis on representations and transformations, thus it focuses on the structure and processing of representations within a cognitive system. It examines the role of material media in which representations are embodied and in the physical processes that propagate representations across media.

It also analyses how information is transformed through the different representations.

The hospital department case: A communication context exemplified

In order to compare the two frameworks and their outcomes, we use a case taken from a department at a hospital in Sweden. We made a study at the setting, where we did close observations and interviews with staff and patients. Note though that the study is just an example, that we use in order to find out whether the two frameworks could be useful in the design process. We did not do the study with the intention of implement any of the systems.

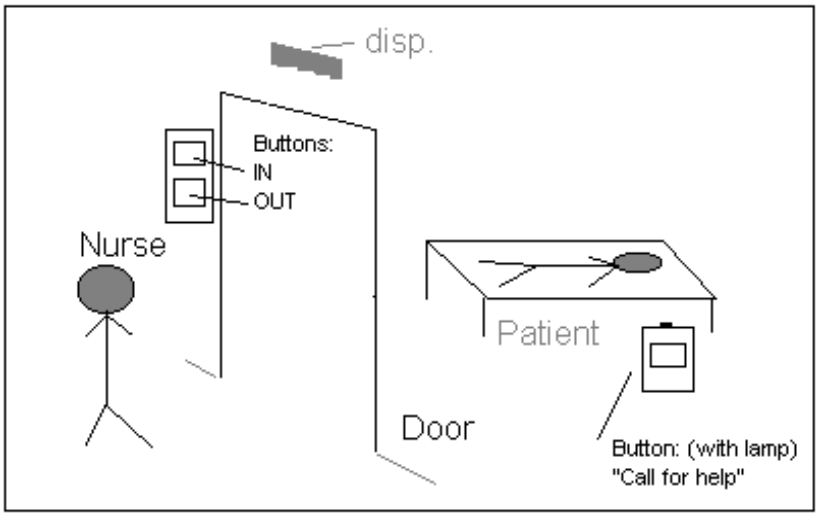
The focus of this study is the usage of an information system used by the employees at the department. The two main purposes of the system is; (1) To keep track of where the employees are located in the department, and (2) to display patients who have called for help, by showing the room number in which this patient is located.

The displays are located in the corridor, hanging from the ceiling. The displays have two windows; one indicating in what rooms the people in the staff is located for the moment; a series of eight room numbers indicated in green. In the other window of the display, the room numbers of patients who need help are indicated in red. This information comes directly after the series of green digits. Whenever a red digit is shown, a signal is also made by the system. The whole series of information roles continuously with a short break of a few seconds.

Different buttons used by staff and patients provides the input to the system. The buttons used by staff to indicate their location are located beside every door. Whenever they enter a room they are supposed to push this button, and this lightens an indicator located near the button. When they leave the room they push this button again to reset it, and the indicator is shut of.

The system neither keeps track of *which* nurse was currently in the room nor whether the same nurse pushed more than one button, i.e. forgot to reset one button and then pushed a new button. The buttons for the patients are located near their beds. These buttons were also combined with a lamp, displaying if the button had been pushed.

Figure 2 illustrates how the system is working:



In the next section we will outline two design suggestions built upon the two theoretical frameworks presented. The underlying idea is twofold;

1. To start off from our empirical observations and interpretation in order to come up with design

suggestions relevant for the case and,

2. To let the theoretical framework help us inform those suggestions.

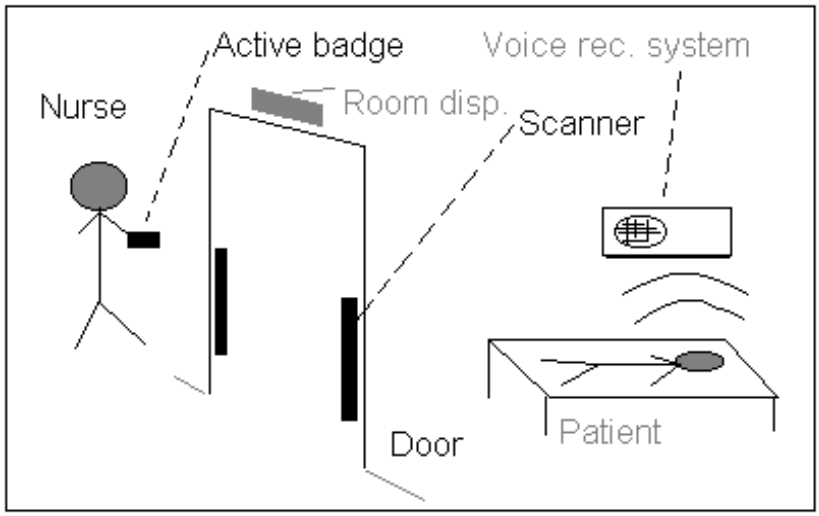
A design suggestion from out of Activity Checklist

Activity Theory takes the activity as the unit of analysis, so our core idea of design will be to formulate which *actions* are to be mediated by the system. To decide upon that we need to take into consideration what *goal* is to be supported by the system.

The main idea was to avoid the problem of having the nurses remembering to turn on and off the help buttons. Since this is a problem concerning *internalization* and *externalization* from the perspective of Activity Theory we tried to make the *operations* necessary to handle the help system automated by necessity in the overall activity (like entering or leaving the room). We also tried to avoid any need of knowledge from the patient to handle the system.

The design we suggest is as follows:

Goal; The patients should get help as soon as possible.
Subgoal; To go through the nursing procedure without having to remember to use the system.
Activities; The operations to fulfil the subgoal is implemented in the systems as badges carried by the nurses. As the doors are always open, a scanner reads the badges whenever a nurse passes a door to a patient room. Two scanners are needed to separate the cases of ”going in” from the ”going out”. To get the nurses attention, the patient just needs to ask for help by saying the word ”Help”. A voice recognition system identifies the call and displays the number of the room where the patient is located. A lamp near the bed also confirms for the patient that the call has been made. In the corridor there is a display showing information, as well from the badges as from the voice recognition system.



The good thing with this design is that the interface is highly transparent (no need for externalization or operations necessary but not related to the main goal or activity). The patient just needs to make an audible call for help, e.g. no more pushing buttons over and over again without proper feedback in terms of not knowing whether the systems has recognized the push. In

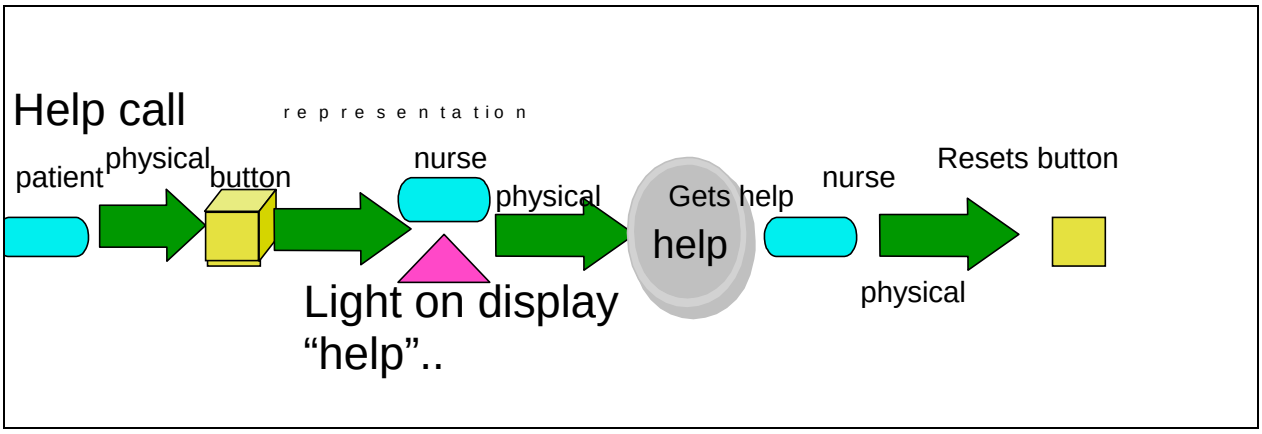
this design an amplitude meter put on the voice recognition system will indicate that a call has been made and then, by a synthetic voice, answer the patient that he or she now have made a call for help.

Note that the usage of natural language may be difficult in some cases, as natural language differs from program languages. Because of this it is important to find words that are clear and different from other words often used in the context of the system. However, as this is a quite broad subject, we leave it out of out discussion.

A design suggestion from out of Distributed Cognition

Distributed Cognition considers the context as a cognitive system, thus taking processes and representations among people and artifacts into account. Our core idea of design is therefore to design an artifact with a proper representation without redundant needs neither for checking displays or for turning on and off symbols representing present location, nor missing a call for help.

The Distributed Cognition analysis (following the scheme of Yvonne Rogers) shows that the existing design involves a lot of physical interaction. Those actions are easy to forget since they are not necessary in order to help the patient. For instance resetting the patients 'call for help button' when leaving the room, already in hurry to help the next patient.



As shown in the picture there are several things needed to be done in a certain order to make the existing design work.

Since this design alternative really is no alternative to consider (it is not used since no one is relying on the idea that everyone goes through the scheme just illustrated and there is no co-operative support), we down below outline an alternative design taking those facts (the need to avoid a lot of physical interaction with the system and the need for co-operative support among nurses) into consideration.

Our design is as follows:

Concerning redundancy, the system described above are redundant in the way that staff cannot know from out of the system if the patient has got help. The signal sounds either way. This may force the nurses to check, and re-check, whether the needing patient really *got* help or not.

If the system works as the above mentioned, with badges, scanners and voice recognizers, another function may be added to the system. That is, when the patient calls for help the number of the room is displayed and a sound is added (just as before). After this, the system keeps track of the locations of the nurses, and when a nurse enters the room, that is, the number on the room of her location matches the room for the patient, the signal stops and a green lamp shows next to the number of the calling patient on the screen.

Whilst the other design suggestion mostly concerned the main activity of making a call for help and providing information needed for the nurses to know which patient had made the call, this suggestions concerns the idea to distribute the problem of ”helping patients when they need it” by providing the nurse team with a ”group awareness and group activity technology”.

Concluding remarks

The designs suggested in this paper are grounded in the two different theoretical frameworks. We have tried to explain our point of view of those two theoretical frameworks quite thoroughly in the paper, in order to point out the specific differences.

It is clear that the frameworks supports different kinds of design ideas, like focus of the design in terms of activities, goals and operations (e.g. Activity Theory) or representations and processes (Distributed Cognition).

It is also clear that the frameworks highlight different problems needed to handle within the design of the total environment, consisting of both the technical arrangements as well as the functionality of the information technology.

We do not think this little comparison on how the frameworks can be used is enough for us to make any judgement upon which framework is better or richer to use in a design process.

However, we have come to the conclusion that it is good to have a contextual framework to structure a design and it also provides the opportunity to discuss and compare different specific problems related to design of artifacts for distributed cognition. We also ask ourselves whether these ideas really came out of the theories, or if the design suggestions came to us first, intuitively, and that we made an effort of placing those design suggestions into the theories. Perhaps just having knowledge *about* these kinds of theories and their main ideas may give enough support in design processes of the above mentioned kind.

References

Bergqvist, J., Dahlberg, P., Kristoffersen, S., and Ljungberg, F. Moving Out of the Meeting Room: Exploring support for mobile meetings To be presented at the European Conference on Computer Supported Cooperative Work, September 1999

Borovoy, R., Martin, F., Vemuri, S., Resnick, M, Silverman, B., Hancock, C. (1998). Meme Tags and Community Mirrors: Moving from Conferences to Collaboration. In Proceedings of ACM 1998 Conference on Computer Supported Cooperative Work (pp. 159-168)

Cole, M., and Engeström, Y. (1991). A cultural-historical approach to distributed cognition., In G.Salomon, ed., Distributed Cognition (pp. 1-47). Cambridge: Cambridge University Press.

Dahlberg,P., Redström, J., Fagrell, H., (1999). People, Places and the NewsPilot. In CHI'99 Extended Abstracts. ACM Press.

Holmquist, L.-E., a. Joakim Wigström and J. Falk (1998). "The Hummingbird: Mobile Support for Group

Awareness", Demonstration at ACM 1998 Conference on Supporting Group Work, ACM Press.
Huchins, E., (1996). Cognition in the Wild, MIT Press, Cambridge.
Kaptelinin, V., and Nardi, B., (1997) The Activity Checklist, Report, Department of Informatics, Umeå University, Sweden.
Kuutti, K., (1994) Information systems, cooperative work and active subjects: The activity-theoretical perspective, Ph.D. thesis, University of Oulu, Oulu, Finland.
Kuutti, K., and Arvonen, T., (1992). Identifying potential CSCW applications by means of Activity Theory concepts: A case example, In Proceedings of ACM 1992 Conference on Computer Supported Cooperative Work, edited by J. Turner and R. Kraut, pp. 233-240, ACM Press, New York
Nardi, B., (1992). Context and Consciousness: Activity Theory and Human-Computer Interaction, MIT Press, Cambridge.
Rogers, Y., and Halverson, C., (1998) An Introduction to Distributed Cognition: Analyzing the Organizational, the Social, and the Cognitive to Understand, Design and Implement CSCW Applications, Tutorial at ACM 1998 Conference on Computer Supported Cooperative Work, Seattle, WA.