What impact has external cognition had on HCI?

One of the main uses of the external cognition approach in HCI has been to enable researchers and designers to articulate designs and phenomena in terms of a set of core properties and design dimensions — which they did not have access to before. In so doing, a language, couched in how people manipulate representations, interact with objects, etc., at an interface, was provided, helping researchers to select, articulate and validate particular forms of external representation in terms of how they could support various activities being designed for. Besides the originators of the theoretical frameworks, they have been used by a number of others to inform the design of various interfaces. Their emphasis on determining the optimal way of structuring and presenting interactive content with respect to the cognitive effort involved can be viewed as being generative Although largely superseded by contemporary theories that address a broader range of user aspects, the extended cognition approach still has much to offer in terms of helping designers select and create interactive visualizations, feedback and multi-modal representations.

5.2 DISTRIBUTED COGNITION

The distributed cognition approach considers cognitive phenomena in terms of individuals, artifacts, and internal and external representations (Hutchins, 1995). It provides a more extensive account compared with external cognition. Typically, it involves describing a "cognitive system," which entails interactions among people, the artifacts they use, and the environment they are working in. It was initially developed by Hutchins and his colleagues in the late 1980s and proposed as a radically new paradigm for rethinking all domains of cognition (Hutchins, 1995). It was argued that what was problematic with the classical cognitive science approach was not its conceptual framework *per se,* but its exclusive focus on modeling the cognitive processes that occurred within one individual. Alternatively, Hutchins argued that what was needed was for the same conceptual framework to be applied to a range of cognitive systems, including socio-technical systems at large (i.e., groups of individual agents interacting with each other in a particular environment).

Part of the rationale for this extension was that, firstly, it was assumed to be easier and more accurate to determine the processes and properties of an "external" system — since they can arguably, to a large extent, be observed directly in ways not possible inside a person's head — and, secondly, they may actually be different and thus unable to be reduced to the cognitive properties of an individual. To reveal the properties and processes of a cognitive system requires doing an ethnographic field study of the setting and paying close attention to the activities of people and their interactions

with material media (Hutchins, 1995). These are conceptualized in terms of "internal and external representational structures" (Hutchins, 1995, p135). It also involves examining how information is propagated through different media in the bounded cognitive system.

Distributed Cognition in a Nutshell

The distributed cognition approach provides an event-driven description of the information and its propagation through a cognitive system. The cognitive system might be one person's use of a computational tool, such as a calculator; two people's joint activities when designing the layout for the front page of a newspaper, using a shared authoring tool, or more widely, a large team of software developers and programmers, examining how they coordinate their work with one another, using a variety of mediating artifacts, such as schedules, clocks, to-do lists and shared files.

The granularity of analysis varies depending on the activities and cognitive system being observed and the research or design questions being asked. For example, if the goal is to examine how a team of pilots fly a plane — with a view to improving communication between them — then the focus will be on the interactions and communications that take place between them and their instruments, at a fine level of granularity. If the goal is to understand how pilots learn how to fly — with a view to developing new training materials — then the focus will be at a coarser grain of analysis, taking into account the cultural, historical, and learning aspects involved in becoming a pilot.

The description produced may cover a period of a day, an hour or only minutes, depending on the study's focus. For the longer periods, verbal descriptions are primarily used. For the shorter periods, micro-level analyses of the cognitive processes are meticulously plotted using diagrammatic forms and other graphical representations. The rationale for performing the finer levels of analysis is to reveal practices and discrepancies that would go unnoticed using coarser grains of analysis, but which reveal themselves as critical to the work activity.

A distributed cognition analysis typically involves examining:

- The distributed problem-solving that takes place (including the way people work together to solve a problem).
- The role of verbal and non-verbal behavior (including what is said, what is implied by glances, winks, etc. and what is not said).
- The various coordinating mechanisms that are used, e.g., rules, procedures.
- The various ways communication takes place as the collaborative activity progresses.

- How knowledge is shared and accessed.

It should be stressed that there isn't one single way of doing a distributed cognition analysis. Within work settings, data is collected and then analyzed and interpreted in terms of work practices, routines and procedures followed, and the work arounds that teams develop when coping with the various demands placed upon them at different times during their work. Breakdowns, incidents or unusual happenings are highlighted, especially where it is discovered that excessive time is being spent doing something, errors were made using a system, or a piece of information was passed on incorrectly to someone else or misheard.

Problems can also be described in terms of the communication pathways that are being hindered or the breakdowns arising due to information not propagating effectively from one representational state to another. This level of analysis can reveal where information is being distorted, resulting in poor communication or inefficiency. Conversely, it can show when different technologies and the representations displayed via them are effective at mediating certain work activities and how well they are coordinated.

Hutchins emphasizes that an important part of doing a distributed cognition analysis is to have a deep understanding of the work domain that is being studied. He recommends, where possible, that the investigators learn the trade under study. This can take a team of researchers several months and even years to accomplish and in most cases this is impractical for a research or design team to do. Alternatively, it is possible to spend a few weeks immersed in the culture and setting of a specific team to learn enough about the organization and its work practices to conduct a focused analysis of a particular cognitive system.

The distributed cognition approach has been used primarily by researchers to analyze a variety of cognitive systems, including airline cockpits (Hutchins and Klausen, 1996; Hutchins and Palen, 1997), air traffic control (Halverson, 1995), call centers (Ackerman and Halverson, 1998), software teams (Flor and Hutchins, 1992), control systems (Garbis and Waern, 1999), emergency rooms (Artman and Waern, 1999), emergency medical dispatch (Furniss and Blandford, 2006) and engineering practice (Rogers, 1993, 1994). One of the main outcomes of the distributed cognition approach is an explication of the complex interdependencies between people and artifacts in their work activities. An important part of the analysis is identifying the problems, breakdowns and the distributed problem-solving processes that emerge to deal with them. In so doing, it provides multi-level accounts, weaving together "the data, the actions, the interpretations (from the analyst), and the ethnographic grounding as they are needed" (Hutchins and Klausen, 1996, p19). For example, Hutchins' account of ship navigation provides several interdependent levels of explanation, including how navigation is performed by a team on the bridge of a ship; what and how navigational tools are

used, how information about the position of the ship is propagated and transformed through the different media and the tools that are used.

As a theoretical approach, it has received considerable attention from researchers in the cognitive and social sciences, most being very favorable. However, there have been criticisms of the approach, mainly as a continuation of an ongoing objection to cognitive science as a valid field of study and, in particular, the very notion of cognition (e.g., Button, 1997). In terms of its application in HCI, Nardi (1996, 2002) has voiced her concerns about its utility in HCI. Her main criticism stems from the need to do extensive fieldwork before being able to come to any conclusions or design decisions for a given work setting. Furthermore, she points out that there is not a set of interlinked concepts that can be readily used to pull things out from the data. In this sense, Nardi has a point: the distributed cognition approach is difficult to apply, since there is not a set of explicit features to be looking for, nor is there a check-list or recipe that can be easily followed when doing the analysis. It requires a high level of skill to move between different levels of analysis, to be able to dovetail between the detail and the abstract. As such it can never be viewed as a "quick and dirty" prescriptive method. The emphasis on doing (and interpreting) ethnographic fieldwork to understand a domain means that at the very least, considerable time, effort and skill is required to carry out an analysis.

Where the distributed cognition framework can be usefully applied to design concerns, is in providing a detailed level of analysis which can provide several pointers as to how to change a design (especially forms of representation) to improve user performance, or, more generally, a work practice. For example, Halverson (2002) discusses how in carrying out a detailed level of analysis of the representational states and processes involved at a call center, she was, firstly, able to identify why there were problems of coordination and, secondly, determine how the media used could be altered to change the representational states to be more optimal. Hence, design solutions can start to emerge from a detailed level of analysis because the nature of the descriptions of the cognitive system is at the same level as the proposed design. In other words, the low-level nature of a distributed cognition analysis can be most useful at revealing the necessary information to know how to change a design, when it has been identified as being problematic.

There have also been various efforts to develop more applied distributed cognition methods that are more accessible and easier to apply. One in particular that has been used by a number of researchers is Distributed Cognition for Teamwork (DiCoT) — essentially a structured approach for analyzing work systems and teamwork (Blandford and Furniss, 2005; Furniss and Blandford, 2010). The approach draws on core ideas from DC theory and combines them with more practical aspects of contextual design (Beyer and Holtzblatt, 1998; Holtzblatt and Jones, 1993), that resulted in a comprehensive set of underlying themes and principles intended to guide researchers in knowing what to focus on when analyzing and interpreting data from workplace settings. Themes include physical layout, information flow, and the design and use of artifacts; principles include subtle bodily supports (for example, pointing on a screen while replying to someone who walks in and asks a question is part of the mechanism of remembering where they are in a task) and arrangement of equipment (e.g., where computers, printers, etc., are in an office determines who has access to and

can interact with information). The themes and principles are intended to help researchers organize their field observations into a set of interdependent models that can help elicit insights about user behavior.

Contextual design

Contextual design (Beyer and Holtzblatt, 1998) is not a theory but an applied approach that was developed to deal with the collection and interpretation of ethnographic findings. It is only briefly mentioned here because it was an important component in the development of the applied DiCoT framework. It is concerned with explicating context and the social aspects of user-interaction and how to use this to inform the design of software. It focuses on how to progress layers of abstractions rather than bridging analysis and design through examining the detail of each. It is also much more prescriptive, promoting a process of transforming data into a set of abstractions and models. The outcome is a very hands-on method of applying research findings, that has proven to be highly successful, with many other practitioners having adopted and used it. Part of its attraction lies in its conceptual scaffolding; it offers a step-by-step approach with various forms to fill in and use to transform findings into more formal structures.

A benefit of bringing together the various strands of the DC literature is to provide a more structured framework that can help researchers and developers to identify the strengths and limitations of the current artifact designs. In so doing, it should enable them to reason systematically about how to re-design the work settings, in terms of considering new technologies, work practices, physical layout, etc. Others have also started to use it to analyze work practices, including software team interactions (Sharp and Robinson, 2008) and mobile healthcare settings (McKnight and Doherty, 2008).

What impact has the distributed cognition approach had on HCI?

The distributed cognition approach has been widely used in HCI to analyze existing practices and to inform new and redesigns by examining how the form and variety of media in which information is currently represented might be transformed and what might be the consequences of this for a work practice. Partially in response to the criticism leveled at the difficulty of applying the distributed cognition approach, Hutchins and his colleagues (Hollan et al., 2000) set an agenda for how it could be used more widely within the context