A Brief Introduction to Distributed Cognition©

Yvonne Rogers

Interact Lab, School of Cognitive and Computing Sciences, University of Sussex, BRIGHTON, BN1 9QH, UK

August 1997

Summary

Distributed Cognition is a hybrid approach to studying all aspects of cognition, from a cognitive, social and organisational perspective. The most well known level of analysis is to account for complex socially distributed cognitive activities, of which a diversity of technological artefacts and other tools and representations are an indispensable part.

History and Background

The Distributed Cognition (dcog) approach was developed by Ed Hutchins ad his colleagues at University California, San Diego in the mid to late 80s as a radically new paradigm for rethinking all domains of cognitive phenomena. The traditional view of cognition is that it is a localised phenomenon that is best explained in terms of information processing at the level of the individual. In contrast Hutchins was making the claim that cognition is better understood as a distributed phenomenon.
The theoretical and methodological base of the distributed cognition approach derives from the cognitive sciences, cognitive anthropology and the social sciences.

Explanation

Cognitive phenomena that the distributed cognition approach is concerned with cover a wide spectrum; from analysing the properties of processes of a system of actors interacting with each other and an array of technological artefacts to perform some activity (e.g. flying a plane) to analysing the properties and processes of a brain activity (e.g. perceiving depth). To date, however, most attention has focused on cognitive systems of work practices, like cockpits (Hutchins and Klausen), air traffic control (Halverson), software teams (Flor) and engineering (Rogers).

The Distributed Cognition approach emphasises the distributed nature of cognitive phenomena across individuals, artefacts and internal and external representations in terms

of a common language of 'representational states' and 'media'. In so doing, it dissolves the traditional divisions between the inside/outside boundary of the individual and the culture/cognition distinction that anthropologists and cognitive psychologists have historically created. Instead, it focuses on the interactions between the distributed structures of the phenomena that is under scrutiny.

A main point of departure from the traditional cognitive science framework is that, at the 'work setting' level of analysis, the distributed cognition approach aims to show how intelligent processes in human activity transcend the boundaries of the individual actor. Hence, instead of focusing on human activity in terms of processes acting upon representations inside an individual actor's heads the method seeks to apply the same cognitive concepts, but this time, to the interactions among a number of human actors and technological devices for a given activity. In addition, other concepts coming from the social sciences are utilised to account for the socially-distributed cognitive phenomenon. These include notions like intersubjectivity, organisational learning and the distribution of labour.

At the brain level of analysis, the distributed cognition approach tries to account for the interactions that occur in the brain between the processing units at the neural level. For example, Hutchins cites how Hinton and Becker built a computational model that shows how two visual modules are able to share a representation of a visual world in such a way that through their interaction they can recover depth, something that neither can sense alone. On the surface, this level of analysis appears to have little in common with an analysis of the social and cultural practices of, a working practice, like air traffic control. However, Hutchins argues that the same maths that is used to construct computational models of the former can also be applied to cultural-cognitive mechanisms in the latter (e.g. modeling the interactions between brain areas and the social practices between communities but at different levels of integration).

Within the distributed cognition framework, therefore, one can adopt different units of analysis, to describe a range of cognitive systems, whereby some subsume others (Hutchins, 1995). One can focus on the processes of an individual, on an individual in coordination with a set of tools or on a group of individuals in interaction with each other and a set of tools. At each level of description of a cognitive system, a set of cognitive properties can be identified; these properties can be explained by reference to processes that transform states inside the system.

Within each system, cognitive activities are viewed as computations which take place via the "...propagation of representational state across media" within a functional system, whereby the 'representational media may be inside as well as outside the individuals involved". (Hutchins, 1995, p. 373). Hence, the media refer to both internal (e.g. an individual's memory) and external representations (maps, charts, computer database, scribbles etc.). The states of the representation refer to how the various resources of knowledge and information are transformed in the conduct of an activity.

General Properties of Cognitive Systems

A general assumption of the distributed cognition approach is that cognitive systems consisting of more than one individual have cognitive properties that differ from those individuals that participate in those systems.

Another property is that the knowledge possessed by members of the cognitive system is both highly variable and redundant. Individuals working together on a collaborative task are likely to possess different kinds of knowledge and so will engage in interactions that will allow them to pool the various resources to accomplish their tasks. In addition much knowledge is shared by the individuals, which enables them to adopt various communicative practices (e.g. not having to spell out every time they meet someone what they know about a practice, procedure or state of affairs).

Another important property is the distribution of access to information in the cognitive system. Sharing access and knowledge enables the coordination of expectations to emerge which in turn form the basis of coordinated action.

Examples

i) Hutchins (1995) study of navigation on a ship

An example provided by Hutchins (1995) of a distributed cognition analysis of a cognitive system is the navigation of a ship. Here, his focus is on the cultural-cognitive processes that take place when steering a ship into harbour. At a micro-level of analysis, Hutchins describes the detailed coordination of representational states across media that take place for the relatively simple, but critical coordinating activity of plotting a fix. This involves several members of the navigation team taking and plotting bearings of the ship as it comes into the harbour at regular intervals of every 3 minutes or so. It is a highly routinized activity, requiring the complex coordination of people and artefacts - all of which is crucial for ensuring the ship is on course. At a macro level of analysis, Hutchins also describes how these coordinated activities of plotting a fix provide a structured experience for the team members enabling more generally, individual learning of procedures and the cultural practices of the navy. As noted by Hutchins (1995, p374):

"...since most learning in this setting happens in the doing, the changes to internal media that permit them to be coordinated with external media happen in the same processes that bring the media into coordination with one another. The changes to the quartermasters' skills and the knowledge produced by this process are the mental residua of the process".

Hutchins goes into great detail analysing how the various representational state are propagated across media for this collective navigation activity and in so doing show how 'the properties of this computational system are as much determined by the nature of the representational media and the pattern of interconnection among representations as they are by the cognitive properties of the individual actors". (Hutchins, 1992, p.2).

This distinction is critical for the distributed cognition approach, emphasising again the importance of focusing on the distribution of cognition through analysing the interactions between the different 'components' (i.e. the changes in representational state) of the system over time and place.

2) Hutchins and Klausen (1996) study of cognition in the cockpit
The study analyses the interactions of internal and external representational structure and the distribution of cognitive activity among members of a cockpit flight crew. The analysis shows a pattern of cooperation and coordination of actions among the crew which is viewed at one level as a structure for propagating and processing information and at another level a system of activity in which shared cognition emerges.

3) Rogers (1992, 1993) study of engineering practice
Rogers carried out a study of how networking technology has changed the working practices of an engineering company. Through doing a Distributed Cognition analysis she was able to reveal various breakdowns that occurred in the work activities and the mechanisms by which the group had adapted their working practice to overcome them.

4) Halverson's (1995) study of air traffic control
Halverson carried out a study of how air traffic controllers interact with a radar system when controlling air traffic. From her observations and analysis she was able to make recommendations of what was important to retain of the existing design with a view towards developing future automated decision-making tools for the controllers.

Methodology

The distributed cognition approach uses a number of methods: from detailed analysis of video and audio recordings of real life events, to neural network simulations and laboratory experiments. The type of methodology adopted depends on the unit of analysis that is being adopted and the level at which the cognitive system is being explained.

For cognitive systems that are being described at the 'work setting' level it is imperative to carry out extensive field work and become familiar with the work practice. This entails observing the work, making copious field notes, recording events and then transcribing and encoding these. An important part of this kind of ethnographic analysis is re-representing the raw data collected at different levels of abstraction and detail, focusing on the changes in representational state in the cognitive system. Theoretical analyses are also carried out in relation to the assumed properties of distributed cognitive systems.

Discussion

One of the key questions often asked about the distributed cognition approach is how does it differ from a traditional cognitive science explanation of human activity. Furthermore, what leverage is gained from giving an account of collaborative activities in terms of 'propagation of representational state across media'? In support of the distributed cognition approach it can be said that it provides a framework and analytic methodology for examining the interactions between people and artefacts which is not possible with traditional approaches to cognitive task analyses. In doing so, it can highlight the complex interdependencies between people and between people and artefacts in their collaborative activities, which in turn, can lead to a better understanding of why

seemingly trivial breakdowns in the communications and interactions between them can have significant and sometimes drastic consequences.

A problem with the distributed cognition approach is that it is not a methodology that one can readily pick off the shelf and apply to a design problem. Moreover it is no panacea for CSCW or HCI. A lot of time needs to be spent understanding the concepts and learning to interpret and re-represent data captured in work settings. For example, a tremendous amount of time can be spent analysing just a 2 second clip of video. One might reasonably ask is it worth it? Is there a more pragmatic approach to using the framework for applied means?

A challenge for the distributed cognition approach, therefore, is how to integrate concepts from the social and organisational sciences with the cognitive analysis of 'representational states'. In particular, it is difficult to combine macro-level theories, such as organisational learning, with micro-level detailed descriptions of the intersubjectivity that goes on between two people during a two second encounter. The goal is to find an appropriate level of analysis and explanatory description for the problem that is being addressed.

Application to CSCW

Whilst primarily a framework for providing an explanatory account of distributed cognition, the distributed cognition approach has great potential for being applied to CSCW. Rogers and Halverson (1995, 1996) have given tutorials with this endeavour in mind at ECSCW'95 (Stockholm) and CSCW'96 (Boston). At one level, it can be very useful in identifying problems with existing work practices and use of technological artefacts. At another, it can highlight what is salient and important in existing system designs, that needs to be retained in subsequent designs intended to augment, enhance or replace current systems and ways of working.

Key Publications

Flor, N.V. and Hutchins, E. (1992) Analyzing Distributed Cognition in Software Teams: a Case Study of Collaborative Programming During Adaptive Software Maintenance. In Empirical Studies of Programmers: Fourth Workshop, eds. J. Koenemann-Belliveau, T. Moher. and S. Robertson, Norwood, NJ: Ablex.

Halverson, C.A. (1992) Analyzing a Cognitively Distributed System: a Terminal Radar Approach Control. Unpublished Masters diss., Cognitive Science Department, University California San Diego, CA.

Halverson, C.A. (1994) Distributed Cognition as a theoretical framework for HCI: Don't throw the Baby out with the bathwater - the importance of the cursor in Air Traffic Control. Tech Report No. 94-03, Dept. of Cognitive Science, University of California, San Diego.

Halverson, C.A. (1995) Inside the Cognitive Workplace: New Technology and Air Traffic Control. PhD Thesis, Dept. of Cognitive Science, University of California San Diego.

Hutchins, E. and Klausen, T. (1996). Distributed Cognition in an Airline Cockpit. In Communication and Cognition at Work, eds. D. Middleton and Y. Engeström, Cambridge: Cambridge University Press.

Hutchins, E. and Palen. L. (in press). Constructing Meaning from Space, Gesture, and Speech. To appear in the Proceedings of NATO sponsored workshop on Discourse, Tools, and Reasoning:Situated Cognition and Technologically Supported Environments (Lucca, Italy; 1993).

Hutchins, E. & Norman, D. A. (1988). Distributed cognition in aviation: a concept paper for NASA (Contract No. NCC 2-591).Department of Cognitive Science. University of California, San Diego.

Hutchins, E. (1995). Cognition in the Wild. MIT Press.

Hutchins, E. (1995). How a cockpit remembers its speed. Cognitive Science, 19, 265-288.

Hutchins, E. (1991). Organizing Work by Adaptation. Organizational Science, 2: 14-39.

Hutchins, E. (1990). The Technology of Team Navigation. In Intellectual Teamwork, eds. J. Galegher., R.E. Kraut, and C. Edigo, Hillsdale, N.J.: LEA.

Latour, B. (1996). Review of E. Hutchin's Cognition in the Wild. Mind, Culture and Activity, 3 (1) 54-63.

Nardi, B.A. (1996). Studying Context: A Comparison of Activity Theory, Situated Action Models and Distributed Cognition. In Nardi, B. (ed) Context and Consciousness: Activity Theory and Human-Computer Interaction. MIT Press.

Nardi, B.A. (1996). Concepts and Consciousness: Four Voices. To appear in the Australian Journal of Information Sciences, Sept. 1996.

Nickerson, R.S. (1993). On the distribution of cognition: some reflections. In Saloman, G. Distributed Cognitions. CUP.

Rogers, Y. (1992.) Ghosts in the Network: Distributed Troubleshooting in a Shared Working Environment. In Proceedings of the Conference on Computer-Supported Cooperative Work, eds. J. Turner and R. Kraut, 346-355. ACM: New York.

Rogers, Y. (1993) Coordinating computer-mediated work. Computer-Supported Cooperative Work, 1, 295-315.

Rogers, Y. (1994.) Exploring obstacles: Integrating CSCW in evolving organisations. In CSCW'94 Proceedings, ACM, NY.67-78.

Rogers, Y. and Ellis, J. (1994). Distributed Cognition: an alternative framework for analysing and explaining collaborative working. Journal of Information Technology, 9(2), 119-128.

Ross, S., Ramage, M. and Rogers, Y. (1996). PETRA: Participatory evaluation through redesign and analysis. Interacting With Computers, 7 (4), 335-360.

Scaife, M. and Rogers, Y. (1996). How do graphical representations work? International Journal of Human-Computer Studies, 45, 185-213.

Zhang, J., & Wang, H. (1995). The integration of internal and external information in numerical tasks. Proceedings of the Seventeenth Annual Conference of the Cognitive Science Society (pp. 791-795). Hillsdale, NJ: Erlbaum.

Zhang, J. & Norman, D. A. (1994). Representations in distributed cognitive tasks. Cognitive Science, 18, 87-122.

Zhang, J., & Norman, D. A. (1994). The representation of relational information. Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society (pp. 952-957). Hillsdale, NJ: Erlbaum.

Zhang, J. (1991). The interaction of internal and external representations in a problem solving task. Proceedings of the Thirteenth Annual Conference of Cognitive Science Society. Hillsdale, NJ: Erlbaum.

☐
☐
☐
☐
☐