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The application of individually and socially distributed cognition in workplace studies: two peas in a pod?

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ABSTRACT
This paper compares and contrasts two forms of distributed cognition - one looking at how an individual interacts with one or more artefacts, the other looking at how groups of people interact with or without artefacts. Whilst the two approaches have many similarities, they can be seen to have significant practical and theoretical differences and merit very different approaches, particularly in their application.

Keywords
Distributed cognition, ethnography, tool use, groups, collaboration, co-operation.

INTRODUCTION

'Traditionally, human cognition has been seen as existing solely "inside" a person's head, and studies on cognition have by and large disregarded the social, physical, and artifactual surroundings in which cognition takes place' (Salomon, 1993).

Distributed cognition has been suggested as a useful way of understanding how work is performed, in terms of the division of labour between people and artefacts and between people, with the often explicit aim of designing new work practices and technology. Several forms of distributed cognition have been described (such as those by Hutchins, 1995a; Heath and Luff, 1991 and Salomon, 1993). In addition, many approaches have been used to investigate 'distributed cognition' or DC (ethnomethodology, activity theory, situated cognition, to name just a few). However, only one approach takes a truly cognitive perspective in the terms used by cognitive scientists such as Newell and Simon (1972), Neisser (1967), and Pylushyn (1984) - that of Edwin Hutchins. In a series of papers, Hutchins and his research collaborators have built an approach to the study of the extended cognitive system. However, within this framework, two very distinct areas have arisen from both practical and methodological concerns with data collection. These two areas can be described as individual distributed cognition (IDC) and socially distributed cognition (SDC).

individual distributed cognition: this term is applied to cognitive systems involving a single actor, and one or more artefacts (cognitive artefacts, Norman, 1991). Good examples of such studies have included the use of a 'flight bug' (Hutchins, 1994, 1995b), and the solution to the Tower of Hannoi puzzle (Zhang and Norman, 1994). These studies have investigated how human intellectual resources engage with, and cannot usefully be seen as separate from, the physical resources in the world in task performance (Norman, 1993).

socially distributed cognition: this term is used specifically to investigate multi-person activities, often in concert with physical artefacts that act as cognitive resources (as in IDC), but also act as intermediaries in communication between individuals. Seminal examples of this include Hutchins' studies of navigational systems and aircraft cockpits (1995a,b). A further distinction within this has since arisen (Perry and Macredie, unpublished), in which SDC systems can be divided into two forms:

a) well structured systems, in which all of the problem solving resources are initially known to the 'functional system'.

b) ill-structured, or 'messy' systems, in which the participants, processes and artefacts involved are initially under-, or unspecified.

The question we seek to answer in this paper is whether IDC and SDC are a part of the same research toolbox, or whether they are sufficiently distinct to be considered as independent areas of investigation. The conclusions drawn from this question will inform DC analysts about how they need to approach problem solving in the extended cognitive system that they are trying to understand.

IDC AND SDC - A COMMON HERITAGE

IDC and SDC both derive from classical cognitive science, which provides a conceptual framework to examine intelligence and problem solving. Classical cognitive science explores how information is represented in the cognitive system, and how these representations are transformed, combined and propagated through the system in goal oriented behaviour (Simon, 1981). Analysis of an extended - or distributed - cognitive system uses the same language to describe problem solving, but it is not reliant on the internal, mental resources of one individual.

At this point, it is important to recognise that the particular form of distributed cognition that concerns us in this paper is that of, or derived from, Hutchins' work. We do not attempt to look at the other forms of social analysis that investigate how work is distributed, and this is not an attempt to label or re-classify them as SDC. These other approaches do not primarily focus on the information-processing element of activity; indeed several argue strongly against the idea that information processing, or 'cognitive' systems exist at all (cf. ethnomethodology). However, we can learn from these other approaches by drawing from their concerns with methodology, such as ecological validity, and more esoteric considerations, such as positivism, realism and reflexivity.

Both the IDC and SDC approaches to distributed cognition involve the analyst describing activity as a computation realised through the creation, transformation and propagation of representational states (Hutchins, 1995a,b). As actors bring representations into co-ordination with each other, information can be propagated through the extended cognitive system, being continually modified and processed until the desired result is reached. We therefore have a cognitive system mediated through the expression of features arising through non-neurological mechanisms. Whilst processing of the information available to the group is analogous to an individual's internal cognitive capabilities, the architecture of this activity differs significantly.

The components involved in problem solving make up the *functional system* (Hutchins, 1995a) of activity. The functional system includes all of the representation carrying and representation-transforming entities involved in the problem solving activity. A DC analysis examines the means by which these are organised to perform problem solving. An important feature of DC is that it treats the functional system as a computational system in the same way that cognitive science describes mental processes. Examining the functional system as a computational system allows the analyst to examine the emergent behaviours generated through interactions between its component parts. DC provides a unique insight into how technology and the socially generated media of communication act upon and transform representations, and in doing so, perform computations (i.e. they are involved in information processing activity). The aim of DC is therefore to understand how intelligence is manifested *at the systems level* and not the individual cognitive level (Hutchins, 1995a).

Primarily, studies into IDC and SDC investigate representations and the processes that transform them. It is important to recognise at this point that cognitive science (as opposed to cognitive psychology) does not use the term cognition as being unique to humans (McCarthy, 1979; Pylushyn, 1984). At the centre of the study of cognitive systems lies the idea of problem solving and goal seeking behaviour. Essentially all cognitive systems can be *described* in this way, regardless of their computational structure, even parallel distributed processing (connectionist) systems (Johnson-Laird, 1984). An early thinker in cognitive theory, Neisser (1967) defined cognition as referring 'to all of the processes by which the sensory input is transformed, reduced, stored, recovered, and used'. Descriptions of 'cognition', as opposed to 'psychology', therefore consider the abstract machinery of problem solving and the organisation of knowledge about the problem domain (i.e. knowledge representation).

DIVERGENCE

Whilst theoretically similar in the computational stance taken by both IDC and SDC, the two forms begin to be seen as radically different under investigation *in practice*. Whilst one (IDC) examines the use of tools, the other takes a sociological bent, involving communication between individuals. Methodologically, the differences become much more polarised. Studies of individuals with tools are seen as being relatively straightforward, and an experimental, functional, or protocol analysis based study is often chosen, in the rational/logical positivist tradition, with its own concerns and values. On the other hand, SDC raises a different set of epistemological questions. Whilst the use of tools is seen as important, and can be investigated with similar techniques to IDC, the primary feature of the research is into the investigation of social co-ordination through communication. The approach used is almost exclusively ethnographic, and as a consequence the concerns of practitioners are very different and a interpretive and reflexive stance is taken - it is heavily influenced by the traditions of sociology and anthropology in symbolic interactionism, ethnomethodology and conversation analysis (see Hammersley and Atkinson, 1995).

Particular differences between the two are shown in the chart overleaf:

Chart demonstrating important differences between IDC and SDC:

Features	**IDC**	**SDC**
Control	Centralised in the individual's mind.	Emergent, arising out of the interaction of multiple actors - no central executive.
Tool use	Artefacts are used as cognitive resources.	Artefacts are cognitive resources as well as mechanisms for co-ordinating distributed cognitive resources (i.e. meta-resources).
Cognitive approach	Serial cognitive process.	Parallel, distributed process.
Investigation and analysis	Quantitative/Experimental or Functional analysis.	Qualitative/Interpretative analysis.
Focus	Show where representations reside, and where rules or processes can be externalised in environmental constraints.	Shows the co-ordination of collaborative activities through an examination of the representations passing between actors.

In addition to the incorporation of artefacts in analysis (as in IDC), the cognitive process can also be described as being distributed over a number of people co-operating through social mechanisms. Hutchins (1994; 1995a) describes this as 'socially distributed cognition'. The unit of analysis may consist of any number of representations, embodied in people, computerised artefacts or non-technological artefacts. Investigation of the social protocols that maintain and co-ordinate the individual processors is important in specifying the structure of the information processor. The goal of analysis is therefore to describe how 'the distributed structures, which make up the functional system, are coordinated by analysing the various contributions of the environment in which the work activity takes place, the representational media [....], the interactions of individuals with each other and their interactional use of artefacts' (Rogers, 1993, p. 297). The analysis of an SDC system therefore goes far beyond simply looking at the matching of the individual's cognitive resources with their physical artefacts in task resolution, but involves other, and strikingly different, resources that are accessed through socially determined mechanisms.

SDC is unlike IDC because social systems consist of a number of autonomous agents, and there is no central executive controlling their activities - although cultural or other organisational phenomena may determine aspects of the division of labour. This is analogous to the work of Rumelhart, McClelland, *et al* (1986) on emergence in parallel distributed processing systems and is a departure from the classical approach to cognition, which is considered to be a serial process. Like social systems, PDP systems are distributed over a number of units and have emergent computational properties arising through the interaction of these organised and self-organising elements.

Understanding how this division of labour operates is central to our understanding of work organisation and working practices (Clegg, 1994). Distributing work across a group of agents must involve the organisation of that group to co-ordinate activity. To solve a problem collaboratively, the division of labour must operate so that work is broken into parts so that individuals can bring their expertise to bear on sub-tasks, before re-incorporating the sub-task with the global task. However, within the distributed cognitive system, problem solving expertise lies not only in the knowledge and skills of the individuals, but in the organisation of those individuals. This organisation may be determined through the context of their work environment and the configuration of the tools that they use (Hutchins and Klausen, 1996).

The activities that a study of SDC involves itself in is a very different one to that of the study of IDC; and these differences can lead divergence across a wide range of theoretical and methodological issues. The study of distributing problem solving activities over cognitive artefacts is essentially a problem studied by psychologists, whilst investigations into socially distributed activities involve more interdisciplinary researchers working within a sociological paradigm, often one in which ethnomethodological, symbolic interactionist or conversation-analytic influences are prevalent. These disciplines take an epistemological stance against the quantitative methodologies employed in IDC, and indeed see all activities as falling into the social arena: in effect, looking at activities as 'individual' is meaningless. Critically, these approaches also take a stance against 'cognitivism' (Coulter, 1979; Button *et al.* 1995), looking at it as a representational tool rather than as an ontological 'fact'. They ask whether the cognitive paradigm (and consequently, DC) is anything more than an analytic device for examining, and reducing the complexity of, action.

These questions raising an epistemological query against cognitivism and DC are indeed complex. However, to an extent these issues can be sidestepped within the analysis of collaborative work through adopting a hermeneutic, interpretivist approach. We do not need to argue about the validity of the approach,

and instead can argue that we are looking for a (and not *the*) rich description of how problem solving can take place in a setting with artificially defined boundaries (i.e. set by the analyst). If we look at DC as providing a representational tool for systems analysis, and not as a true description of activity (as with realism), setting down universal laws (as in positivism), then these issues can be put to one side. However, this discussion demonstrates the extent to which sociological and philosophical concerns will affect the conduct of a DC analysis that moves beyond looking at an individual.

DISCUSSION

The focus of the study of distributed cognition is on the computational characteristics of the functional system in the performance of work. DC allows researchers to better understand how the problem-solving element of work operates in a real world setting, involving individuals or multiple agents, limited by their constraints and drawing from resources in the work setting. The framework allows the analyst to examine cognitive activities within settings that may be rich in physical and cultural resources for organising behaviour. It provides a means of describing structures in the world, embodied in artefacts and the physical environment, and how these can be used to co-ordinate collaborative action.

However, differences appear that split the study of distributed cognitive systems firmly into two distinct camps, and these are distinguished by practical, epistemological and ontological concerns. Whilst at a one level, they are unified in looking at problem solving as an external symbol system (Newell and Simon, 1981), at others they are strongly divergent, and cannot be said to have many similar characteristics. It is therefore only in the *analysis* of such 'cognitive' systems in distributed problem solving that both IDC and SDC concur. This, however, is crucial - it means that workplace settings can be described in a similar language that unifies people, artefacts and the environmental settings that are used as constraints and resources in behaviour. Setting aside concerns over whether the descriptions of such systems are 'true' cognitive functional systems, or just analytic devices, this is a valuable finding because we can describe systems as being composed of representations and processes that provide co-ordination (Perry, 1998). It therefore provides us with a common framework to discuss activity in the workplace - whether it is collaborative, or conducted by an individual.

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