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ABSTRACT Among the many contested boundaries in science studies is that between the cognitive and the social. Here, we are concerned to question this boundary from a perspective within the cognitive sciences based on the notion of distributed cognition. We first present two of many contemporary sources of the notion of distributed cognition, one from the study of artificial neural networks and one from cognitive anthropology. We then proceed to reinterpret two well-known essays by Bruno Latour, 'Visualization and Cognition: Thinking with Eyes and Hands' and 'Circulating Reference: Sampling the Soil in the Amazon Forest'. In both cases we find the cognitive and the social merged in a system of distributed cognition without any appeal to agonistic encounters. For us, results do not come to be regarded as veridical because they are widely accepted; they come to be widely accepted because, in the context of an appropriate distributed cognitive system, their apparent veracity can be made evident to anyone with the capacity to understand the workings of the system.

Keywords Bruno Latour, cognitive versus social, distributed cognition, Edwin Hutchins

Distributed Cognition:

Where the Cognitive and the Social Merge

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Among the many contested boundaries in science studies is that between the cognitive and the social. One of the most notorious invocations of this boundary occurred in Latour & Woolgar's postscript to the second edition of *Laboratory Life* [(1986): 280] where they proposed 'a ten-year moratorium on cognitive explanations of science' and promised 'that if anything remains to be explained at the end of this period, we too will turn to the mind!' Here the cognitive and the social are presented as binary opposites, with the social clearly dominant.[1]

Appeals to the cognitive aspects of science occur in several very different contexts. One is found primarily in Anglo-American analytic philosophy of science, where 'cognitive' is associated with concepts such as 'normative' and 'rational', both being intended in a substantive rather than a merely instrumental sense. We mention this philosophical context only to make clear that this is not the notion of the cognitive we are concerned

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with here. We are concerned, rather, with the empirical conception of the cognitive as it appears in the context of the cognitive sciences, where the focus is on the mechanisms of such cognitive capacities as, for example, vision, memory, language production and comprehension, judgment, and motor control.

Even from the perspective of the cognitive sciences, however, opposition between the cognitive and the social has been pervasive. One of us once published a reply in *Social Studies of Science* under the title 'The Cognitive Construction of Scientific Knowledge', intending an explicit contrast with the social construction of scientific knowledge.[2] That paper was quite tolerant in not insisting that the cognitive story could be the whole story about any scientific episode. Nevertheless, any social story was viewed as distinct and, indeed, supplementary to, the cognitive story. This has been pretty much the standard view among those who have explicitly pursued a 'cognitive approach' to science studies.[3]

Rejection of a sharp boundary between the cognitive and the social can now be found in several quarters, including even philosophy, where 'social epistemology' is becoming a recognized category.[4] Here we will be concerned only with a questioning of the boundary coming from within the cognitive sciences. This questioning consists of an inquiry into forms of distributed cognition.

Distributed Cognition

We will consider just two of many contemporary sources of the notion of distributed cognition within the cognitive sciences. The first is due to McClelland, Rumelhart and their associates in the Parallel Distributed Processing Group in San Diego, CA, USA, during the early 1980s. Among many other things, this group explored the capabilities of networks of simple processors thought to be at least somewhat similar to neural structures in the human brain. It was discovered that what such networks do best is recognize and complete patterns in input provided by the environment. The generalization to human brains is that man recognizes patterns through the activation of prototypes embodied as changes in the activity of groups of neurons induced by sensory experience. But if something like this is correct, how does man do the kind of linear symbol processing required for activities such as using language and doing mathematics?

The answer given by McClelland et al. was that man does the kind of cognitive processing required for these linear activities by creating and manipulating external representations. These latter tasks can be done by a complex pattern matcher. Consider the following simple example introduced by McClelland et al. [(1986): 44–48]. Try to multiply two three-digit numbers, say 456 × 789, in your head. Few people can do even this very simple arithmetical operation in their heads. Here is how many of us learned to do it:

$$\begin{array}{r} 456 \\ \underline{789} \\ 4104 \\ 3648 \\ \underline{3192} \\ 359784 \end{array}$$

This process involves an external representation consisting of written symbols. These symbols are manipulated, literally by hand. The process involves eye-hand motor coordination and is not simply going on in the head of the person doing the multiplying. The person's contribution is: (1) setting up the problem in a physical form; (2) doing the correct manipulations in the right order; (3) supplying the products for any two integers, which can be done easily from memory.[5]

Note that this example focuses on the process of multiplication, not the product, and not on knowledge of the answer. Advocates of distributed cognition like to talk about cognitive tasks. Of course, if the task is done right, one does get the right answer, but the focus is on the process rather than the product. This leads one to emphasize the cognitive system instantiating the process rather than cognition simpliciter. In our multiplication example, the cognitive system performing the multiplication consists of a person plus the produced external representation and the means to produce it. All are necessary to complete the cognitive task. So here we have a simple case in which cognition is distributed among man and his artifacts.

Our second source for the concept of distributed cognition within the cognitive sciences is the study by Ed Hutchins (1995) of traditional navigation in his book, *Cognition in the Wild*. What Hutchins adds to the picture, besides a wealth of detail, is that one and the same cognitive system may include a number of humans as well as many external representations and other artefacts.[6] His ethnographic study of 'pilotage', that is, navigation near land as when coming into port, demonstrates that individual humans may be merely components in a complex cognitive system. No one human could physically do all the things that must be done to fulfill the cognitive task, in this case repeatedly determining the relative location of a traditional navy ship as it nears port. For example, there are sailors on each side of the ship who telescopically record angular locations of landmarks relative to the ship's gyrocompass. These readings are then passed on, for example by the ship's telephone, to the pilothouse where they are combined by the navigator on a specially designed chart to plot the location of the ship. In this system, no one person could possibly perform even just these three tasks in the required time interval. And only the navigator, and perhaps his assistant, knows the outcome of the task until it is communicated to others in the pilothouse.[7]

In Hutchins' analysis, the social structure aboard the ship, and even the culture of the US Navy, play a central role in the operation of this cognitive system. For example, it is important for the smooth operation of the system that the navigator holds a higher rank than those making the sightings. The navigator must be in a position to give orders to the others. The navigator, in turn, is responsible to the ship's pilot and captain for producing locations and bearings when they are needed. So the social system relating the human components is as much a part of the whole cognitive system as the physical arrangement of the required instruments. To a large extent it is the social components that determine how the cognition is distributed throughout the system. Here the cognitive and the social merge.[8]

Accepting the idea that cognition may be distributed throughout a system comprising both humans and artifacts may tempt one to ascribe cognitive agency to the larger system, to say it is the system that knows, perhaps even consciously knows [Clark (1997); Knorr-Cetina (1999)]. We think this temptation should be resisted. It is possible to think of the whole system as producing knowledge while maintaining that it is only the humans who come to know the results, in some completely ordinary sense of knowing [Giere (2002a)]. Of course, some humans come to know the results by being part of the cognitive system, but most humans come to know the results only through authenticated reports. If there is such a thing as an 'act' of knowing, it is the same for human participants and observers. In the end, all possess the same knowledge.

Reinterpreting Latour: I

From its title alone, 'Visualization and Cognition: Thinking with Eyes and Hands,' one might expect that this paper [Latour (1986)] expresses views close to those of Hutchins and other champions of distributed cognition. Not quite. It does very nicely present a number of examples that can easily be reinterpreted as cases of distributed cognition. For example, the use of chemical formulas in organic chemistry was introduced by Berzelius in 1813 and developed to its mature form by Dumas in the 1830s. Assuming that the basic constituents in reactions are conserved, one can represent chemical reactions by equations in which the numbers of all constituents are the same on both sides of the equation. That is, the equation must balance. One can literally do theoretical chemistry by manipulating these symbols as in the following example:

$$C^8H^8 + H^4O^2 + Ch^4 = C^8H^8O^2 + Ch^4H^4. \text{ [sic]}$$

Understood in terms of distributed cognition, these formulas are external representations that form part of a distributed cognitive system for exploring possible reactions in organic chemistry. That is, the cognitive process of balancing an equation does not take place solely in the head of some person, but consists of interactions between a person and physical, external representations.[9]

Latour [(1986): 22] claims that 'the history of science is the history of . . . [such] innovations.' This is, of course, an exaggeration, but Latour is clearly onto something important. The invention of new forms of external representation and of new instruments for producing various kinds of representations has played, and continues to play, a large role in the development of the sciences. From a cognitive science perspective, both sorts of invention amount to the creation of new types of distributed cognitive system. So, for us, the notion of distributed cognition brings under one category such things as Cartesian coordinates and the telescope, both of which are widely cited as major contributions to the Scientific Revolution.

We differ with Latour, however, on the nature of the role played by external representations. For Latour, the significance of external representations lies in their being two-dimensional, relatively stable, mobile, and capable of being superimposed. Thus, information originally spread out both spatially and temporally can be brought together in a 'centre of calculation' where it can be combined in new ways. This concentration of information, Latour claims, confers authority and power on those who control it. And it leads others to align themselves with such powers, thus increasing still further their authority and power. In a struggle for dominance, whether in science, politics, or war, those with the most and strongest allies win.

From our point of view, the importance of distributed cognitive systems is simply that they make possible the acquisition of knowledge that no single person, or a group of people without instruments, could possibly acquire. And combining representations in ever simpler forms makes it possible for individuals with only the power of a pattern matching brain to comprehend and appreciate what has been learned. This is a cognitive scientific explanation for how forms of external representation can provide scientific results with the power to persuade others of their veracity. To simplify in Latourian fashion, results do not come to be regarded as veridical because they are widely accepted; they come to be widely accepted because, in the context of an appropriate distributed cognitive system, their apparent veracity can be made evident to anyone with the capacity to understand the workings of the system.[10]

Reinterpreting Latour: II

In *Pandora's Hope*, Latour [(1999b): ch. 2], presents a detailed case study of a scientific investigation that seeks to determine whether the Amazonian rainforest is encroaching on the adjacent savannah or if the savannah is encroaching on the rainforest.[11] Latour uses this example to argue for his account of circulating reference. In the present section, we will reinterpret his account of this case in terms of distributed cognitive systems.

The first step in a cognitive analysis is to identify the overall cognitive task. In this case, the scientists are trying to determine the relative movement of the savannah and the rain forest over time. Their task is to create a cognitive system in which this question can be answered by superimposing botanical and soil analyses. The primary cognitive system consists of a team of scientists, a map, a coordinated grid system, a field notebook and two specialized subsystems – one botanical and one pedological (pedology is a soil science). The team of scientists consists of two pedologists, a botanist, and a geographer. The basic methodology of their study is to create a Cartesian grid that spans a section of the forest and the adjacent savannah on which both the botanical and the pedological data can be superimposed. In order to create the grid, the geographer finds the coordinates of the plot on a map and creates a corresponding grid on the ground. The grid is created by a series of numbered tags, which represent the map coordinates. Once the grid is in place, the botanist takes samples of the flora from each grid carefully noting the exact location of each sample in the field notebook. The pedologists work in the same grid carefully taking soil samples also noting the location of each sample in the field notebook [Latour (1999a)].

A number of interesting features emerge when we evaluate this study in terms of distributed cognitive systems. First, we notice that the creation of the grid is an epistemic action. The grid serves as a means for transforming the environment so that future problems become more tractable. Imagine how difficult it would be to compare the soil and botanical data without an explicit framework for matching the different kinds of data. Second, we see the reliance on external forms of representation. The series of tags and the constant filling of the field notebook are examples of the use of external representations to structure the environment in such a way as to make the problem's solution apparent to a person whose built-in cognitive equipment consists primarily of a pattern-matching brain. Finally, notice that the epistemic actions and the external representations serve as ways of letting patterns emerge. The idea behind taking two sources of data, which will be later superimposed, is to set up a framework in which patterns become more visible. Without this structure, the patterns revealed by the soil and botanical samples would remain hidden. These examples all highlight the heavily 'scaffolded' nature of scientific practice.[12]

The botanical and pedological subsystems are also ripe for a cognitive system analysis. The botanical samples are physically organized in a series of cubbyholes, like the mailboxes often found in any US academic department. Each 'mailbox' corresponds to one of the grids established by the geographer with metal tags. Within each cubbyhole, all plant specimens of the same species are kept together in manila folders [Latour (1999a)]. This method of organizing specimens is a way of distributing cognition. In this case, the physical arrangement of the boxes serves as a way of organizing information, so that an external structure replaces the need for explicit cognitive computations. The botanists could have tried simply to memorize the locations of each sample, but the box system is an easier and much more reliable way to make the same information accessible.

The pedologists also distribute their cognition in a number of interesting ways. First, they maintain their grid in the forest by use of a Topofil. Latour describes how the Topofil works [(1999a): 43]:

A spool of cotton thread unrolls evenly and spins a pulley that activates the cogwheel of a counter. Setting the cogwheel to zero, the pedologist can get from one point to the next. Upon arrival at his destination, he simply cuts the thread with a blade set near the spool and ties off the end to prevent any untimely unrolling. A glance at the window on the counter tells the distance he has traveled to within a meter. His path becomes a single number easily transcribed into a notebook and – a double advantage – takes on material form in the thread that remains in place.

This passage reveals the complex cognitive interaction between the scientists and their tools. The Topofil serves several functions in that it both creates a representation of distance in meters and provides a physical manifestation of the grid on which the entire study is based. Again, this example highlights the utility of the distributed cognitive system analysis. Here we see how scientific instrumentation helps solve complex scientific problems. The line acts as an external representation freeing the scientist to focus on emerging patterns.

A second way in which pedologists distribute their cognition is by the use of a pedocomparator. A pedocomparator is a shallow shelf with small boxes arranged in orderly columns and rows. The pedologists fill the small boxes with their soil samples according to a particular protocol. Rows correspond to sample sites and columns correspond to depths. Each box is labeled with the coordinates of the grid system. The interesting thing about the pedocomparator is the fact that, when full, it allows the scientists to read a pattern directly off its arrangement of soil samples. As the soil changes from clay (which forests prefer) to sand (which savannahs prefer) it changes color. When the samples are arranged in the pedocomparator, the pattern of coloration reveals the changes in soil composition [Latour (1999a)]. This simple fact is a striking illustration of the power of the distributed cognitive systems approach to capture scientific practice. The scientists and the samples of dirt arranged in a pedocomparator form a cognitive subsystem in which the interaction between the scientists and an environment structured in a particular way allows the scientists to solve a problem by simply recognizing a pattern. In this case, the pedologists determine where the transition between clay and sand occurs by recognizing a simple pattern of color in the full pedocomparator.[13]

We have left much of Latour's case study untranslated because these examples sufficiently highlight the distributed nature of scientific cognition. A full cognitive systems analysis would continue by describing how samples are turned into quantifiable data, how the two sets of data are superimposed and how the combined data is used in the creation of a scientific paper. In addition, Latour deliberately excludes sociological factors from his analysis, which means that, apart from the basic organization of the research team, we cannot describe in more detail the merging of the cognitive and the social in this case. However, it is important to note that, as in Hutchins' example, this account is incomplete without some story about how social structures shape the distribution of tasks in the cognitive system. Latour says [(1999a): 44]:

Of course, had I not artificially severed the philosophy from the sociology, I would have to account for this division of labour between

French and Brazilians, mestizos and Indians, and I would have to explain the male and female distributions of roles.

This sociological element is exactly what is missing from a full account of this scientific episode as an example of distributed cognition. The cognitive and the social merge precisely because we cannot say how the scientists work together to complete their cognitive task without describing their social interactions.

Conclusion

We conclude by noting a point of agreement between Latour and ourselves. Following the passage from Latour and Woolgar's new 'Postscript' quoted at the beginning of the present paper, there is this sentence: 'If our French epistemologist colleagues are sufficiently confident in the paramount importance of cognitive phenomena for understanding science, they will accept the challenge.' This suggests that the kind of cognitive explanations being rejected are those to be found in books such as Claude Levi-Strauss' *La Pensée Sauvage* (1962) or in more general appeals to a scientific 'mentalité'. Latour seeks simpler, more verifiable, explanations. As he says in a paper cited earlier [Latour (1986): 1], 'No "new man" suddenly emerged sometime in the sixteenth century. . . . The idea that a more rational mind . . . emerged from darkness and chaos is too complicated a hypothesis.' We agree completely. Appeals to cognitive architecture and capacities now studied in the cognitive sciences are meant to explain how humans with normal human cognitive capacities manage to do modern science. One way, we suggest, is by constructing distributed cognitive systems that can be operated by humans possessing only the limited cognitive capacities they in fact possess.[14]

Notes

1. Here we might note, in justification of our writing the present paper, and somewhat tongue in cheek, that the proposed moratorium has long since run out.
2. The reply, Giere (1992), was in response to Pickering (1991).
3. See Carruthers et al. (2002), Churchland (1989), Nersessian (1995), and Thagard (1991).
4. See Fuller (1988), Longino (1990), Schmitt (1994), and Solomon (2001).
5. The case is in principle similar, though graphically less dramatic, if we imagine the calculation being done with an electronic calculator (or even a computer). The person still has to perform some simple pattern-matching actions such as entering the numbers and pushing the multiply button. The external representations and operations are all built into the calculator and operate 'automatically'. They are no less external representations for all that.
6. For a simpler example, though with a stronger anthropological and less cognitive orientation, see Goodwin (1995).
7. Note that this not merely a case of division of labor. In the first place, since the product is a cognitive product, knowledge, it would be a case of the division of cognitive labor. Second, this is not merely a case of collective cognition (a subcategory of distributed cognition), where new knowledge is produced by combining the knowledge of several individuals. Rather, the knowledge is produced by a carefully organized system including several individual humans together with appropriate instruments. It is this

whole system that we call a cognitive system. See also Goodwin [1995: 256] who describes a similar situation as 'not just a division of labor, but a division of perception'.

8. Hutchins' model of distributed cognition is applied to Karin Knorr-Cetina's study of experiments at CERN in Giere (2002a). See Knorr-Cetina (1999).
9. This particular example is taken from Klein (1999).
10. We say 'apparent veracity' because, of course, truth is not transparent. What comes to be accepted as correct on the basis of very good evidence might turn out not to be correct after all.
11. This essay was originally published as Latour (1995).
12. In the cognitive science community [Clark (1997)], it is common to describe as 'scaffolding' instruments and other features of the environment organized to facilitate cognitive activities. The metaphor conjures up images of medieval churches, some of which are even today covered with scaffolding for reconstruction.
13. The conclusion of this study was that the forest is slowly encroaching on the savannah. The scientists determined this was that case because the soil started to turn from sand to clay 15 to 30 m before the beginning of the forest. They proposed a follow-up study in which they were to examine whether earthworm activity is responsible for this mysterious change in soil composition.
14. For a distributed cognitive systems approach to scientific cognition generally, see Giere (2002b).

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