Is the Reproduction of Expertise Limited by Tacit Knowledge ?

The Evolutionary Approach to the Firm Revisited by the Distributed Cognition Perspective

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Christian Bessy

Abstract

The aim of this paper is to re-examine the proposition advanced by the evolutionary approach to the firm (Nelson and Winter, 1982) that the knowledge an organisation possesses is reducible to the knowledge of its individual members. Such a proposition may explain the importance accorded by this approach to the tacit dimension of knowledge held by individual members. Rather than focus on the opposition between tacit and codified knowledge, we propose to pay more attention to the way knowledge is distributed, not only, among individuals, but also between individuals and their socio-material environment. We present a somewhat different distributed cognition approach that offers an understanding of learning as a permanent reorganisation process of representational media that are inside as well as outside the individuals involved. In this perspective, we conclude that the restrictions underlined by the evolutionary approach on the reproduction of organisational capabilities and the training of new workers are not so strong.

Key words : firm, expertise, learning, tacit knowledge, distributed cognition, collective memory.

La transmission du savoir technologique est-elle limitée par la connaissance tacite ?

Révision de l'approche évolutionniste de la firme dans l'optique de la cognition partagée

Résumé

L'objectif de ce document est de réexaminer la thèse de l'approche évolutionniste de la firme (Nelson, Winter, 1982) selon laquelle la connaissance d'une organisation se réduit à la connaissance individuelle de ses membres. Cette thèse peut expliquer l'importance accordée par cette approche à la connaissance tacite détenue par les individus. Plutôt que de nous focaliser sur l'opposition entre connaissance tacite et connaissance codifiée, nous nous intéressons à la façon dont la connaissance est partagée, non seulement parmi les individus, mais aussi entre les individus et leur environnement socio-matériel. Nous présentons une approche de la cognition partagée qui conduit à percevoir l'apprentissage comme un processus permanent de réajustement de media représentationnels, internes et externes aux individus. Dans cette optique, nous concluons que les restrictions formulées par l'approche évolutionniste quant à la transmission des capacités organisationnelles et la formation de nouveaux employés ne sont pas aussi fortes.

Mots-clefs : firme, savoir technologique, apprentissage, connaissance tacite, cognition partagée, mémoire collective.

INTRODUCTION

Following the seminal work of Nelson and Winter (1982), the evolutionary approach to the firm has contributed significantly to an improved understanding of the firm. With the notion of organisational capability, this approach identifies a central aspect of industrial organisation that is not taken into account by traditional theories of the firm. In particular, the contractual approach (Tirole, 1989) can be criticised because it does not treat the costs inherent in the storage of technological knowledge coming from repeated interactions between the members of the organisation. By neglecting this kind of cost, the neo-classical theory of industrial organisation proceeds in much the same manner as it does when it considers perfect contracts without transactions costs.

If certain complementarities exist with Transaction Costs Economics (Winter, 1991), one of the main differences of the evolutionary approach comes from what is taken to be the pertinent unit of analysis. By focussing on the firm level rather than on the level of the transaction, the evolutionary approach seeks to explain how technological knowledge is created, preserved and transferred ? In this manner, the evolution of the firm's boundaries is accounted for by an analysis of its cognitive properties. Among these properties, a great emphasis is given to the tacit dimension of knowledge generated by collective learning processes and called "organisational routines" by this approach. These are patterns of interactions that represent successful solutions to the encountered problems. The routinisation of the activity and the spontaneous coordination, which result from a specific organisational context, make it unnecessary to represent or articulate the whole process. Moreover, because of the complexity of such a process, it can not be fully articulated. As a result, the more the dimension of such operational knowledge is tacit and specific to the organisational context, the more the capacity of replication of operations, the training of new workers and the access to new activities are limited (Dosi *et alii*, 1990 ; Teece *et alii*, 1994).

The objective of this text[1] is to re-examine this kind of hypothesis based on the tacit dimension of knowledge and on the specificity of organisational context in which it emerges. In a labour market functioning perspective, this issue is important for understanding today how firms can be efficient and innovative in presence of high turn-over of personnel or, in others words, how they can reproduce their expertise ?

In the evolutionary approach to the firm, organisational routines are embodied in the heads of individuals, without much reference to the fact that they can be partially saved in representational media (e.g. tools, cognitive artefacts…), which are external to individuals. More precisely, only formal records are taken into account and considered as external memories. The underlying proposition of this approach is that the knowledge an organisation possesses is reducible to the knowledge of its individual members. And such a proposition may explain the importance accorded by this approach to the tacit dimension of knowledge held by individual members.

Rather than focus on the opposition between tacit and codified knowledge, we propose to pay more attention to the way knowledge is distributed, not only, among individuals, but also between individuals and their socio-material environment. We present a somewhat different

[1] A first version of this text has been presented to the DRUID (Danish Research Unit for Industrial Dynamics) Conference on Learning Economics, Aalborg, 15-17 June 2000. I thank B. Reynaud et and E. Lorenz for their useful comments on this version.

distributed cognition approach that offers an understanding of learning as a permanent reorganisation process of representational media that are inside as well as outside the individuals involved. Thus we are led to distinguish between different technological knowledge storage processes of which every moment of a practise is simultaneously a part. In this perspective, it seems that the argument based on tacit dimension of knowledge (*versus* codified) for explaining the limited capacity of firms to reproduce their expertise is less relevant.

This perspective coming from new developments within cognitive sciences (Norman, 1994 ; Hutchins, 1995) is not completely new. In a certain way, it extends the paradigm of information processing from individuals to organisations and the idea that the latter reduce the complexity of problems by distributing their resolution according to the capabilities of its members (March and Simon, 1958). As a result, the cognitive properties of the organisation, considered as a whole, can differ from the cognitive properties of its individual members. As Hutchins observes : "These differences arise from both the effects of the interactions with technology and the effects of a social distribution of cognitive labour" (1995, p. 228). If the second effect has been largely analysed by economists who consider firms as cognitive systems, in this text, we are going to focus on the first effect underlined by Hutchins. The attention paid to "interactions with technology" gives a good illustration of his embodied cognition approach that is very different from the classical approach wherein symbol manipulation is the architecture of cognition. His project to re-embody cognition may bridge some gaps between the inner cognitive world and the outer world of perception and action. That leads us to take into account the links between perception and representation in learning processes and knowledge storage. In our prior work on experts, we have shown that these links between perception and representation are central for understanding how expertise is reproduced in a community of practice (Bessy and Chateauraynaud, 1995). Moreover, it seems that such a perspective provides a better understanding of what Nelson and Winter (1982) analyse as automatic behaviours in operational processes.

After a short presentation of the evolutionary approach to the firm, mainly limited to Nelson and Winter's seminal work (1982) and its prolongation to the issue of the coherence of the firm (section 1), we will show how a distributed cognition perspective offers an alternative understanding of knowledge storage processes and their articulation (section 2). In particular, we introduce the role played by perceptual faculties in order to specify the tacit dimension of knowledge (section 3).

1. THE EVOLUTIONARY APPROACH OF LEARNING WITHIN THE FIRM

In their book *An Evolutionary Theory of Economic Change*, Nelson and Winter define mechanisms that account for the evolution and adaptation of firms. In this perspective, how firms achieve their well-adapted state is secondary relative to the basic fact of adaptation. Nevertheless, the authors make hypothesis on the rationality of human behaviour by reference to models of interaction among individuals belonging to the same population that are proper to the evolutionary biology. Individuals, having a limited cognitive capacity, mainly follow habitual patterns of behaviour without any reflexive activity or deliberate choice such as that postulated in the neo-classical approach to human decision-making[2]. In the perspective

[2] On this point, see the debate with Friedman and Machlup.

developed by Nelson and Winter, "decision rules" are given the same status as production technologies, following a naturalist approach in economics founded by classical economists and rehabilitated by Hayek (1980) in order to criticise the constructivist approach[3].

1.1. Organisational learning and the evolution of firm boundaries

The notion of "routine" used by the authors for characterising both individual behaviour and collective action corresponds to any regular and predictable behaviour. There is an analogy between individual skills and organisational capabilities, the latter playing the same role within the organisation as the former at the individual level.

A routine is characterised by three interdependent attributes :

- it is considered to be a program of sequential operations,

- it incorporates the tacit dimension of knowledge which underlies performance,

- it implies that options resulting from a prior learning process are automatically selected, essentially without any deliberate choice.

Nelson and Winter stress the automatic character of human behaviour, in a way that has practical consequences for the success of an activity. Any attempt at deliberate choice in the course of action has counterproductive effects, introducing some hesitation and awkwardness, although deliberate choice increases the potential diversity and the flexibility of behaviour. Nevertheless, in their discussion of search or exploration activities, the authors distinguish between static routines and dynamic routines, the latter being orientated towards learning and the development of new products and processes.

As a result, the representation of the firm in this evolutionary approach is mainly grounded on an auto-organisation model where routines emerge from repeated interactions between agents and their environment. The firm is considered as a system that consists of interlocking, interacting and mutually dependent parts. In such a system, organisational learning is cumulative because of repetition and experimentation. Knowledge gained through learning must be constantly activated in order to be preserved. The main hypothesis is that the organisation remembers by doing and this is the case to a greater extent than for individuals remembering their skills in the process of doing (1982, p. 99). In this perspective, learning is slow and the importance of tacit knowledge limits the articulation and the transmission of organisational capabilities. This has consequences for the capacity to replicate operations, for the training of new workers and for the diversification of activities.

Work on the coherence of the firm (Teece *et alii*, 1994) provides a good illustration of this analytical framework. From empirical data on US corporations, their findings suggest that in so far as firms become more diverse, they add activities that are connected to some portion of existing activities. The authors advance the proposition that "the boundaries of the corporation can be understood in terms of learning, path dependencies, technological opportunities, the selection environment, and the firm's position in complementary assets" (p. 11, 1994).

Regarding organisational learning, the authors point to its incremental dimension. As a trial-and error process, it does not occur in the face of rapidly changing environments. The environment must contain familiar features in order for firms to learn and to have access to new activities. This implies a "path dependency" constraint. They confer great importance to

[3] On this point, see Eymard-Duvernay (1995).

the endogenous transformation of the firm through the time. By making the firm a place of learning, and of knowledge creation and storage, they define the cognitive properties of the firms (in particular the capacity of problem solving) that transcend, in a certain manner, the cognitive properties of their members. However, we can make two criticisms of this :

First, the distribution of knowledge in the firm remains highly influenced by an individualistic approach, although they point to the fact that the firm offers a context and a support to the constitution, the maintenance and the articulation of the different types of knowledge possessed by the individual members.

Second, there is a strong tendency in the demonstration by Teece *et alii* (1994) to emphasise systematically the tacit and idiosyncratic dimension of knowledge. *A contrario*, Nelson and Winter (1982) argue that the degree of tacitness observed depends on a comparison between the costs of articulation and the learning benefits that can be derived from improved articulation.

Before developing these two criticisms, we must examine somewhat more closely the way the evolutionary approach considers the distribution of technological knowledge within the organisation.

1. 2. Organisational memory reducible to individual member memories

The main proposition advanced by the evolutionary perspective is that the knowledge an organisation possesses is reducible to the knowledge of its individual members (Nelson and Winter, p. 104, 1982). Teece *et alii* (1994) quote Simon to emphasise the fact that, "All learning takes place inside individual human heads ; an organisation learns in only two ways : (a) by the learning of its members ; (b) by ingesting new members who have knowledge the organisation didn't previously have. But what is stored in any one head in an organisation may not be unrelated to what is stored in other heads ; and the relation between these two (and other) stores may have a great bearing on how the organisation operates" (1991, p. 125).

However, if it is true that the knowledge of the organisation resides inside individual heads, this knowledge depends on the context, as Nelson and Winter has underlined it in their prior work (1982). This organisational context includes :

- A variety of "external memories" (notion borrowed from Simon) : files, "blueprints", manuals ("how-to-do-it book"), computer stores, etc. These external memories complement and support human individual memories. They can be considered as a part of organisational memory rather than an information storage activity of individual members.

- Also the material states of equipment and work environment. This assumes that the equipment and these structures are relatively stable. Any modification can change the current interpretative context of the information the individuals have. The stability of the environment guarantees a common interpretative context for all the members of the organisation and for the codes and language they use.

- More important, the context of information possessed by one member depends on the information possessed by all the other members. The authors include the linking of the individual memories by prior shared experienced that have established very precisely the specific communication code that underlies routine performance.

On the last point, the authors notice that the role played by shared experiences is undervalued by the view that considers organisational memory as reducible to individual members memories. In a certain way, they recognise the limits of a pure individualistic approach of

learning. Nevertheless, they conclude that the organisational context in which the routine operates "limits the scope of the organisational memory function that needs to be performed" (1982, p. 105)[4]. If each individual member must know his work, there is no need for anyone to know anyone else's job. Nor is it necessary that someone is able to represent or articulate the procedures used by the organisation as a whole, even if, in certain subsystems, the articulation of coordinating information can be useful. Thus, despite these qualifications, it appears that individual memories play the central role in their account.

Moreover, because of the tacit dimension of knowledge held by individual member, this articulation cannot take place. That does not mean that locally an individual member cannot represent his tasks and its links with other ones or that firms cannot maintain formal memories. But these formal records, like "blueprints", are considered by the authors as a small part of what makes up organisational memory in order that the set of routines works effectively. Once this set is committed to memory because of repeated use, blueprints are not necessary saved although they can be useful as models to assess functioning defaults.

The evolutionary approach presents a very similar argument when it analyses organisational evolution in the face of environmental changes. Even if agents can represent and plan their activities locally in order to define better relationships with their surroundings, this design is often impossible at the level of the whole organisation. In this configuration, such an adaptation at the system level appears to be evolutionary, in the sense that system-level changes that result are never represented. There is an auto-emergent solution to the problem encountered prior to its discovery and design by any member of the organisation.

In this perspective the organisational routine that emerges is the product of both local design and evolution. Then the storage of the solution within the system depends on cost considerations relative to future benefits that can be derived from improved articulation. Among the limits on articulation of knowledge, Nelson and Winter emphasise the issue of language-based communication. We will come back to the issue of language later. At this point, keep in mind that the authors consider articulation as a very costly process. Therefore, the learning possibilities of new workers are very restricted, as is the replication of the firm's expertise.

2. A DISTRIBUTED COGNITION PERSPECTIVE

Starting from a somewhat different distributed cognition perspective, we are going to offer an understanding of learning by considering different knowledge storage processes. Instead of conceiving the relation between individuals and environment in terms of moving coded information across a boundary, our approach look for processes of coordination and resonance among elements of a system that includes a person and his socio-material environment. This perspective leads to the study of the cognitive properties of socio-material systems that has implications for the creation and maintenance of knowledge, and its transfer.

This approach is not completely new and has some elements in common with the evolutionary one's. Its specificity comes from a combination of known elements. On the one hand, the idea

[4] However, the authors nuance their reasoning. In certain cases, routinisation doesn't entirely free organisational memory and organisation performance from constraints imposed by the limited capacity of human individual memory. This is the case of flexible performance in which the organisation does different things at different times. The phenomenon of memory loss, because of a too occasional mobilisation of specialised routines, can be lead to disruptive effects on organisational performance. This kind of argument explains the limited capacity of firms to access new activities.

that cognition is collective is at the ground of classical sociology. On the other hand, the organisation theory proposed by Simon and March (1958) considers the organisation not only as a cognitive environment, where cognitive resources are provided to agents, but also as a cognitive system : the organisation reduces the complexity of problems by distributing their resolution according the capabilities of its members[5]. This perspective is also followed by the evolutionary approach.

Moreover, whereas prior Artificial Intelligence works describe individuals as information processing systems (Newell and Simon, 1972), the distributed cognition approach extends this to group of agents by focusing on the directly observable representations they form, propagate and transform within the organisation. Work by Hutchins (1995) provides an excellent illustration.

Nevertheless, there is a strike difference between the traditional Artificial Intelligence approach and Hutchins' project to re-embody cognition, including the cognition of symbol processing. According to him, the traditional hypothesis that symbol manipulation is the architecture of cognition is due historically to the fact that cognitive science has taken the computer as the model of mental functioning. As a result, the integration of cognition with action remains difficult because the traditional hypothesis separates both by definition[6]. Hutchins emphasises that adherents to this tradition, like Newell and Simon (1972), are aware of the presence of a world in which action takes place and they have attempted to take it into account – in particular for integrating the role of emotion into the system of cognition (see *infra*). But this effort has failed. He concludes : "The problem remains that the nature of the interaction with the world proposed in these systems is determined by the assumptions of the symbolic architecture that require the bridging of some gap between the inner, the cognitive world and an outer world of perception and action" (1995, p. 369). On this point, the evolutionary theory proposes a way to respond to this problem by considering decision rules and production technologies as equivalent.

2.1. Different knowledge storage processes

Let us begin by a brief presentation of Hutchins' (1995) analytic scheme of human practice, which has used in the study of ship navigation task. A human practice is considered as a cognitive system composed of different representational media, which may be inside as well as outside the minds of the individuals involved. Each medium supports a representation of the state of the system. The analysis of the cognitive properties of the system consists in following the propagation of different modes of representation and their transformation ; for instance, in the work of navigation, the propagation of visual bearing to the bearing record log, *via* angular and digital representations of the ship's position.

To analyse a human practice, like an entry into a harbour, Hutchins distinguishes three developmental sequences of which every moment of the practice is simultaneously a part. Each of these three dimensions are analysed following the nature of the cognitive process, the rate at which states are changing, the duration of the relevant history of the activity and the residua of the cognitive process (see table) :

- The first, the actual "conduct of an activity" is modelled as the coordination of different representational media that are in relatively intense interaction with one another. It has a

[5] See also Cyert and March (1963).

[6] For earlier critics of this approach see Dreyfus (1972).

relatively short duration and changes (of state) happen quickly. For example, the entry into a harbour involves few hours of preparation and takes about one hour to complete. This "operational" process creates elements of representational structure that survive after the task is achieved. Among these "operational residua of the process" there are individual memories of events and information registered in different artefacts (diagrams, fix position registration...).

- The second, the "training of the practitioners" concerns the experience of the participants who acquire internal organisation (within their minds) that permits them to coordinate with the structure of their surroundings. This acquisition of such skills requires several years. Changes to the organisation of the internal media that participants bring to the job takes place more slowly than the changes to the states that the media support. For example, it takes a longer time to learn how to fix the plot than does to plot a fix. This learning by doing process generates skills and knowledge considered as "mental residua of the process".

- The third consisting in the "evolution of the practice", the solutions of frequently encountered problems are partially saved in the material devices (equipment, instruments[7], spatial arrangement…) and conceptual tools (lexical labels, codes of communication, algorithms, heuristics…), and in the social organisation of the work. This kind of process is much longer and generates "cultural elements" on which agents' daily activities are based.

Three dimensions of a human practice according to Hutchins (1995)

Dimension **Characteristics**	**Conduct of the activity**	**Development of the practitioners**	**Evolution of the practice**
Nature of the process	Intense interaction between the representational media	Internal organisation of their cognitive system	Solutions to encountered problems are partially saved
Rate at which states in that dimension are changing	Quick	Slow	Very slow
The duration of the relevant history of the activity	Short	Some years	Decades or centuries
Residua of the process	*Operational* - Individual memories of events - Information registered in different artefacts	*Mental* - Skills - Knowledge produced by the process	*Cultural elements* Knowledge embodied in material and conceptual tools and in the social work organisation

[7] The hoey, the adelade, the gyrocompass… in the case of navigation.

With this kind of presentation we can have a more complete view of human productive activity and the results it generates. It can be considered as different kinds of knowledge storage processes. Notice that in each dimension the notion of knowledge could have different meanings : "information" or "signals" in the conduct of practice, "skills" or "routines" in the second dimension and "technologies" in the third, including social work organisation. These cultural elements, in turn, structure the way that practitioners represent their tasks and their surroundings and that information is registered and communicated within the organisation[8].

Notice also that "technologies" and work organisation rules can be diffused beyond the boundaries of the organisation in which they have been created. By this, we point out that technological knowledge, even the tacit dimension, need not be idiosyncratic and can be shared by wider communities of practice (Nelson, 1993 ; Wenger, 1998). Furthermore, if the solution to a particular problem is not saved in material and conceptual tools used by the firm, that doesn't prevent any of the participants who were directly implicated by the resolution of the problem to reproduce it in a different organisational setting.

By assuming that all learning takes place inside individual human minds, the evolutionary approach is led to undervalue the third way of storing knowledge we have just mentioned. More exactly this approach underestimates that human beings are adaptive systems continually producing and exploiting a cultural structure. By softening the boundary between individual and context, we have a better understanding of the interactions between different kinds of knowledge storage process. This is arguably more important than the distinction between tacit and explicit knowledge. Moreover, we can comprehend learning as a permanent reorganisation process of representational media, that are inside as well as outside the individuals involved, resulting in an adjusted fit between computational and social organisation.

2.2. Knowledge saved by material tools or how conceptual activities can be transformed in perceptual inferences

By pointing out that technological knowledge is saved in material and conceptual tools, even in pattern of social interactions (conventions, norms of behaviour…) and work organisation (division of labour), one can emphasise the fact that knowledge can be reused, without necessarily entailing codification or intense training[9]. In this section, we are going to focus on the embodiment of technological knowledge in the material environment rather than in conceptual tools[10] or in social institutions, because we want to point out how conceptual activities can be transformed in perceptual inferences.

We must distinguish between the case where the saving of knowledge in the material environment is deliberate and anticipated from the case where this saving follows a more evolutionary process that is not anticipated.

The first case is well represented by material devices. Equipment and tools are considered as entities loaded with knowledge and actions plans, combining cognitive and normative aspects[11]. This is also the case with "symbol-objects", linking action and knowledge,

[8] On the distinction between "information" and "knowledge" and on the fact that "knowledge" can be considered as a structure see Ancori, Bureth, Cohendet (2000).

[9] On this point see also Langlois (2000).

[10] These tools are obviously already been studied by Artificial Intelligence approach.

[11] On this point see also Callon (1993).

execution and evaluation, material properties and representation. According to Norman (1994), the "symbol-object" is both a means of control for the execution of action, and the representation of the state of the object for the evaluation of action. These "experiential artefacts", like gauges, provide a way to experience the situation and then to modify the world, whereas "reflective artefacts" (conceptual artefacts), like symbolic language, provide ways to act upon representations. As long as these experiential artefacts offer external representations, they can serve as perceptual objects. This following example given by Hutchins offers a good illustration : "Consider the pre-plotting of danger bearings. Once this has been done, the determination of whether the ship is standing into danger is made by simply seeing on which side of the line the position of the ship lies. In this case, a conceptual judgement is implemented as a simple perceptual inference" (1995, p. 171).

In this process, there is in fact a redistribution of storage and calculus load between agents and their material environment[12]. With such deliberated redistribution, agents can then allow themselves to be guided by their environment, reducing their computational activity. The computational constraints of problems have been built into the physical structure of the tools. Hutchins gives a lot of examples of such redistribution in piloting activities by showing how the passage from conceptual activities to perceptual ones reduces the cognitive effort of the pilots.

In the second case, saving of knowledge follows a more evolutionary process. An explanation can be proposed by referring to the notion of "concretisation" (*concrétisation*) of technical objects, a notion borrowed from Simondon (1958). With this notion, the French philosopher takes into account the fact that technical objects are not thoroughly determined in contrast with the analytical and abstract principles that can ground them. The "concretisation" process corresponds to incremental adaptations between technical objects and their environment. The less human intervention is needed, the more the technical object is concretised. This "concretisation" could account for any incremental change that the equipment undergoes, resulting to a certain degree in an evolutionary process that is not anticipated at the beginning.

Notice that Dosi and Metcalfe (1991) identify such a process of knowledge embodiment in material environment, but their argument is not completely developed. Moreover, this kind of process does not mean that using concretised objects is specific to workers that operate with them or who are modified by them. If the object is really concretised, it can be used by wider communities of operators that work in the same environment and can be replicated.

Whatever the process of knowledge saving is, the precedent arguments show how material tools can transform difficult tasks into more simple ones like the manipulation of physical objects. These economies come from the fact that the cognitive processes required to manipulate them are not the computational processes accomplished by their manipulation[13]. In a same manner the use of conceptual tools like algorithms or heuristics may entail such economies, as well as the organisation of work. Such distribution of knowledge in the socio-material environment questions the main proposition advanced by the evolutionary approach : the organisation memory is reducible to the individual members' memories.

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[12] In the configuration of "management projects", Garrel and Midler (1995) give a good illustration of the collective knowledge embodied in prototypes. This kind of material entity integrates both perception and representation. On the issue of prototypes, see Dubois (1993).

[13] Regarding this subject Hutchins wonders if the next generation of tools is going to miss this source of computational power with simple physical devices. "The synergy of psychology and artificial intelligence may lead us to attempt to create more and more intelligent artificial agents rather than more powerful task-transforming representations" (1995, p. 171).

In this more extended distributed cognition perspective, the firm's capabilities can be maintained even is some of its members quit. The more the solutions to encountered problems are saved in material and conceptual tools, the more the production process can be replicated and the more the training of new workers is facilitated. Notice that Hutchins has made his study in the US navy in which there is high turn-over rates of personnel.

3. PERCEPTION, REPRESENTATION AND MEMORY

The introduction of perceptual faculties can help us to comprehend the notion of automatic behaviour developed in the evolutionary approach. In particular, it can provide insights into the economies that are inherent relying on automatic behaviour that doesn't entail any deliberation. We have just seen that this automatic behaviour may be possible by saving knowledge in material tools, which can transform complex conceptual activities into perceptual inferences or simple manipulations of physical objects. Now we would like to take a step further by focusing on the links between perception and memory. Our goal is not to give a complete view of the cognitive process, but to take into account the role played by perception and action within this process. This phenomenological perspective, which has been developed by French philosophers like Merleau-Ponty (1945), underlies the contemporary embodied cognition approach. This perspective is not absent in the evolutionary approach when it emphasises the tacit dimension of operational knowledge, but we want to stress more the productive nature of the perceptual system in contrast to the passive recording device view that characterises the traditional Artificial Intelligence perspective. That may provide a better understanding of at least two points advanced by Nelson and Winter's approach : the links between routines and innovation, and the importance of codes of communication in the sharing of common experiences by organisational members.

To illustrate these ideas, I refer to my joint work on expertise in which the significance of perceptual capabilities and of codes of communication in the learning process is demonstrated as long as they link perception and representation (Bessy, Chateauraynaud, 1995).

3.1. "Corporal" and "computational" memories

At the level of the development of practitioners and their capacity for knowledge storage, two types of memory can be discerned. The first one we can call "computational" memory, in the sense of memory supporting symbolic representation and manipulation[14]. This memory is organised in the shape of taxonomical networks, of a structure of categories. The other we can call "corporal" memory, in the sense that it is directly tied to corporal experiences. Individuals have the capacity to embody experiences, to confer on their body a memory, which is neither completely physical, nor completely mental, being structured by strong and discriminate perceptions. We assume that cognitive artefacts, like those we have presented above and especially codes of communication, in which technological knowledge is saved can be considered as mediating structures linking "corporal" and "computational" memories, perception and representation. For instance, in the Hutchin's example, upon seeing on which side of the line (on the chart) the position of the ship lies, one can arrive at an assessment of whether or not the ship is standing into danger.

[14] This does not imply a commitment to the view that the architecture of cognition is symbolic.

Moreover, we assume that the "corporal" memory is predominant and influence the structure of "computational" memory. So, individuals are good at designing internal processes that can be coordinated, primarily by way of sensorial capacities, with the regularities that emerge from their environment. This very phenomenological hypothesis is close to the one about the tacit dimension of knowledge advanced by Nelson and Winter (1982). By emphasising the tacit dimension of knowledge, they refer to Polanyi who emphasises, following Merleau-Ponty (1945), the mobilisation of the (human) body in learning situations. The sensorial capacities of individuals constitute a way of learning that avoids applying sets of rules[15]. At a collective level, this is particularly clear when they consider that organisations "remember by doing" (1982, p. 99), in the sense that "remembering" is achieved largely through exercise and could not totally be assured through formal records. Furthermore, they emphasise the role played by shared experiences in the establishment of a specific code of communication that underlies routine performance.

It seems to us that the distinction we propose between two kinds of memory and of their links may highlight the apparent contradiction within the evolutionary approach between the routine functioning of an organisation and the emergence of innovation. It also provides a good understanding to the economies inherent to specific codes of communication.

3.2. The active and productive nature of the perceptual system in innovation process

In our study on experts (Bessy, Chateauraynaud, 1995), we have pointed out how they can diversify their activity (beyond their domain of specialisation) by adopting a "attitude of comprehension". By this we mean that they can modify their representation by letting themselves be guided by material properties of their environment. That is what it is commonly called intuition. Intuition is related to recognition capacity. We refer to the possession of an elaborate discrimination net, that permits recognition of any one of thousands of different things, as the basic tool of the expert and the principal source of his intuitions. This recognition capacity is linked with repeated experiences that constitute the "corporal" memory and that permits identification of regularities and singularities. This is the focus of certain particular points, through a very progressive trial-and error process, that leads to a new solution and new representation. Thus, this process is not automatic but requires attention to the finest traits of the environment, by mobilising the entire perceptual capacities, if not emotions.

This productive nature of the perceptual system offers a good understanding of how organisations can innovate incrementally by creating small variations around well-controlled routines. In a certain way, this point is mentioned by Nelson and Winter when they underlie that useful questions arise in the form of puzzles inherent in prevailing routines (1982, p. 129). Moreover, it is helpful for the trial-and-error search if the familiar elements of the new combination do not themselves contribute to problems (1982, p. 131). Nevertheless, the authors underestimate the role played by intuition and perceptual capacities in search activity, only underlining that heuristic search procedures can be considered as dynamic routines.

Paradoxically, in his "intuitive model" of rationality, Simon refers to this kind of learning process when he introduces the role played by intuition and emotions in the process of designing new representations (Simon, 1983). Intuition is also related to recognition capacity.

[15] Polanyi concludes "that the aim of a skillful performance is achieved by the observance of a set of rules which are not known as such to the person following them" (quoted by Nelson and Winter, 1982, p. 77).

In new situations, the role of emotion is introduced because of its function of selecting particular things in our environment as attention points. Simon's demonstration stops there, because his main framework of analysis doesn't allow for the integration of cognitive process with perception and action. Nevertheless, his argumentation leads to the issues of acquisition and transfer of knowledge. He distinguishes "cold cognition" from "hot cognition" in which the learning process is supported by intense emotions. We can notice that "hot cognition" supposes a configuration in which people trust one another[16].

3.3. Language as key element of learning

Another skill of experts is their capacity to articulate knowledge and to explain their performance. At the level of the firm, this process constitutes an important source of learning. Nelson and Winter recognise this capacity to articulate much of the knowledge that ordinarily remains tacit : "The same knowledge, apparently, is more tacit for some people than for others" (1982, p. 78).

The hypothesis assumed by the evolutionary approach is that this process is very costly because of the complexity of situations and the limits of symbolic language that can generate semantic ambiguities. Nevertheless, knowledge can be articulated or transferred through a specific code of communication rather than a universal language. What we emphasise in our work is that this kind of language assures the passage from perception to representation. It interconnects the different kinds of memory we have distinguished - not only individual skills and collective capabilities, but also, the "corporal" memories and the "computational" ones. The idea is that conceptual symbols are related to the perceptual traces they represent. The emergence of such a language constitutes a key element of the innovation process because it leads the members of organisation to share their experience[17].

CONCLUSION

From a distributed cognition perspective, we have emphasised the role played by the socio-material environment of agents because of its knowledge storage capacity. In this perspective, differences in the performance of two groups, practising the same activity, can be imputed to the mode of organisation of cognitive processes rather than to the agents' individual competencies alone. There is a link with the notion of organisational routines advanced by the evolutionary approach, but it remains undeveloped since it is prisoner of the idea that organisational memory is reducible to the individual members' memories. That may explain the importance accorded by this approach to the tacit dimension of knowledge held by individual members and to restrictions on the reproduction of organisational capabilities.

By analysing the links between perception and memory, we have tried to highlight the notion of automatic behaviour advanced by this approach and to complement its argument about how firms can develop both routines and new modes of production. Although we emphasise the productive nature of the perceptual system, we would argue that this perspective can be adopted by the evolutionary approach and it does not significantly change its conclusions on firm specialisation.

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[16] This dimension is also emphasised by Wenger (1998).

[17] This aspect has been point out by Narduzzo et al. (1997).

The particular focus on representational media, like material tools, conceptual artefacts or specific languages, provides new fields of investigation. Moreover, the perceptual schemes embedded in representational media can explain their inertia if these media are not modified, or if other media are not created, in order to take into account new environmental conditions. As a consequence, the analysis of the genesis and the transformation of the representational media constitutes one means of comprehending organisational change.

From an empirical point of view, these media, and the interactions they support, are observable at the level of every day practice. Their observation supports the study of the cognitive properties of the socio-material systems in which agents coordinate their activity, rather than a sole focus on the cognitive properties of individual agents.

From a more theoretical point of view, we have shown that the evolutionary approach to the firm developed by Nelson and Winter has heterogeneous foundations as regards cognitive processes. On the one hand, they refer, *via* Simon, to the traditional Artificial Intelligence approach. On the other hand, the reference to Polanyi, and to phenomenology, is important. We can consider that this heterogeneity comes from the fact that at its origins this theory has focused on mechanisms of firm evolution and adaptation. As a result, how firms go about achieving their well-adapted state and how individuals learn is secondary. Nevertheless, notice that today certain authors within the evolutionary approach do try to devise mental models that conform to the ambitions of the rule-based symbol processing perspective. This is the source of some debate within the evolutionary approach (Cohen *et alii*, 1995). This conventional view of cognition as primarily abstract is at the opposite end of the spectrum from the distributed cognition perspective.

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