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COURSE-OF-ACTION ANALYSIS & COURSE-OF-ACTION CENTERED DESIGN

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INTRODUCTION

This chapter presents a theoretical and methodological framework that integrates (1) an approach to the "cognitive task analysis", the "course-of-action analysis" that considers the "cognitive tasks" as embodied, situated, indissolubly individual, collective, cultured and experienced, (2) an approach to "cognitive task design", the "course-of-action centred design", the terms of which are inspired by the "user centred system design" proposed by Donald Norman [26], while introducing a significant difference, which concerns the situation as a whole (spatial, informational, technical, organisational), the training and, more generally, the culture of the operators, thanks to (3) a paradigm of human cognition stemming from theoretic biology, the "enaction paradigm", and various philosophical and scientific contributions that go well beyond "analytical philosophy", "cognitive psychology", and "computer science".

A Long History

This theoretical and methodological framework developed essentially in connection with the creation of computerised and automated work situations (see [31], [46], [52]). It has also proved fruitful concerning non-computerised work situations (e.g. vinegrowing) and some practical situations other than work situations e.g. car driving (in particular including or meant to include different kinds of assistance systems), domestic situations (e.g. including domestic systems of energy control accessible by various media), school situations (in particular integrating software and human tutoring), and more recently, situations of high level sport performance and sport training. The fact that only one artistic situation (the setting up of a play [1]) and a unique situation of artistic reception [36] have been concerned by this approach (amongst other scientific contributions) and neither game situations nor military situations, is purely contingent. These various situations have been tackled in academic and public research, through undergraduate studies and PhD theses in ergonomics, systems control and sporting sciences and techniques. Likewise they have been tackled in ergonomics departments in companies and consulting ergonomics groups.
The initial inspiration for the elaboration of this theoretical and methodological framework first and foremost came from the French language ergonomics tradition and dates back to [27]. Today, this inspiration can be summarised in one directing idea, that of the necessity of an analysis of the actual operators' activities in real work situations for the design of new work situations. However, this elaboration really started in 1979 from a second impulse provided by the reading of Newell & Simon's book entitled "Human Problem Solving" [25] that contributed to the foundation of both laboratory cognitive psychology and Artificial Intelligence. This second impulse in contrast to the first is shared with the other existing approaches of "cognitive task analysis" and "cognitive task design". Indeed, in taking an essential interest in everyday cognition, "cognitive task analysis" can be considered as the response to the strategic criticism that was made to Simon's approach by Noam Chomsky [30], that of being centred on exceptional phenomena, the symbolic problem solving, instead of considering the most common phenomena of human cognition. In parallel, « cognitive task design » can be considered as a contribution to design that goes well beyond Artificial

[1] With thanks to the contributors to the different design studies mentioned and special thanks to René Dufresne for the example of analysis I borrowed from his PhD study at the Canadian Nationa under my direction.

Intelligence systems design. But, because this second impulse has been superimposed on the first one, it has been followed up both literally and in a critical manner in such a way that it is difficult to recognise it in its present form. We will refer to this in the introductory paragraphs of the different sections.

A Pursuit to the Letter

At first, let us consider in "Human Problem Solving" what is followed to the letter by "course-of-action analysis" and "course-of-action centred design". Firstly, of course, it is the proposition to study the "human system" according to "three dimensions of variation" : "tasks", "individual differences" (cultural), and time scale in "behavioural acts" ("performance / learning / development") (op. cit., p. 2). Next, it is "to try to represent in some detail a particular man at work on a particular task" (op. cit., p. 5). Also, "as a scientific bet, emphasis is put on performance" and " learning is considered as a second-order effect" (op. cit., p. 7). Finally the researched theory is "a Process Theory", "Dynamically Oriented", "Empirical, Not Experimental" and "Non-statistical" (op. cit., pp. 9-13), or more precisely :

- "Such a theory describes the time course of behaviour, characterising each new act as a function of the immediately preceding state of the organism and of its environment" (ibidem, p. 11) ;
- "Because of the strong history-dependence of the phenomena under study, the focus on the individual, and the fact that much goes on within a single problem solving encounter, experiments of the classical sort are only rarely useful. Instead, it becomes essential to get enough data about each individual subject to identify what information he has and how he is processing it. This method leads, in conjunction with the content orientation, to emphasising the use of verbal behaviour as data, because of its high output rate. Thus, the analysis of verbal protocols is a typical technique for verifying the theory, and in fact has become a sort of hallmark of the information processing approach. The nature of the theory leads also to a continuous search for new sources of data that can be conjoined to existing data to ease the problem of identification" (op. cit., p12) ;
- "It is difficult to test theories of dynamic, history-dependent systems. The saturation with content – with diverse meaningful symbolic structures – only makes matters worse. There is not even a well-behaved Euclidean space of numerical measurements in which to plot and compare human behaviour with theory. Thus, this book ("Human Problem Solving") makes very little use of the standard statistical apparatus. Theory and data are compared, and some attempts are made to measure and tabulate some comparisons. But our data analysis techniques resemble those of the biochemist or archaeologist more than those of the agricultural experimenter"(op. cit., p. 13).

From this stems a mode of theory and model validation that stresses a systematic description of the verbal protocols gathered in parallel to the progression of the activity in abstract terms that express hypothetical structural invariants and gives a secondary status to the classical experiments and to the statistical treatments. This is why in [25] nearly 200 pages are dedicated to discussing the difficulties in describing some verbal problem solving protocols concerning the "cryptarithmetic puzzle DONALD + GERALD = ROBERT ".

Another characteristic can be added to these first ones : that the limits of the protocols, i.e. the variable "coverage" of the activity by the verbalisations, lead to developing a web of inferences of which the degree of conviction depends upon both the density of the « coverage » and the theoretical construction that is developed (in this case the so-called "problem space"). Once more it is worth while quoting the authors : "Although the detail itself is not very exciting, it is important to see what is going on in this phase of analysis. We are trying to infer from the subject’s verbalisations what he knows and what operations he performs at any point in time. To do so, we must interpret his language – i.e. consider its meaning. Thus, if he says « R is odd », we infer that he knows R is odd. Of course, it is relevant, in principle, to ask whether the given utterance could have been made by chance. If the subject has been asked : « Is R odd or even ? » then his answer that « R is odd » has a fifty-fifty chance of being true, whether the subject knows anything about R or not. As fortune-tellers know, one can often appear to give information by making general enough statements so that the a priori chances of falsification are remote. In our situation, the ensemble against which to view the subject's utterances is the language of the problem space. This makes highly unlikely that « R is odd » will be uttered correctly by chance. More important than the probabilities is the web of inference that goes beyond a short utterance in isolation (« R is odd ») and relates it to other utterances (ex, « Two L's equal an R »). This web of inference varies in its coverage, and not all assertions can be made with considerable assurance" (ibidem, pp. 183- 184).

Course-of-action analysis and course-of-action centred design respect to the letter these characteristics concerning the study of everyday activities and the design of situations in which they are accomplished - with the consequence that, if we were to do things right, the equivalent of 1600 pages of "Human Problem Solving" would be needed in order to set them out ! -, but they radically reject the other characteristics that will be mentioned gradually, in this chapter. From this stems what globally might be called "a radically critical obedience".

Chapter Contents

We will progressively present the various characteristics of course-of-action analysis and course-of-action centred design which stem from this critical obedience to the impulse of Newell & Simon concerning cognitive task analysis and cognitive task design. In section 1 we will present the enaction paradigm and the consequences for cognitive task analysis that have been draw from it : its execution in terms of "course-of-experience" and "course-of-action". In section 2 we will present the principles of the "observatory of course-of-action" and how they are made concrete in the particular studies. In section 3 we will insist on the so-called "principle of the primacy of the intrinsic" in the analysis. In sections 4 and 5 we will present the "semio-logical theoretical framework" for the analysis of the course-of-experience. In section 6 we will be considering in particular the "collective interlinking of the courses-of-action". In section 7 before leaving course-of-action analysis proper for its integration in course-of-action centred design we will present a synthesis of the epistemology and the methodology of the course-of-action analysis. In section 8, we will approach several related questions : that of knowing which kind of synthetic empirical models the course-of-action analysis aims at producing; that of the amphibology of cognitive task design and that of the object of the design considered by course-of-action centred design; that of the distinction between the synthetic empirical models and the synthetic models for design. In section 9 we will show that the dynamic complexity constituted by the human activity imposes, for empirical knowledge as well as for design, an iterative process for the study of situations. We will then finally be able to approach in section 10 "the practice of course-of-action analysis and course-of-action centred design". In particular we will, on the basis of the notion of "exactly useful", specify the articulation which is required between research and development concerning course-of-action analysis and course-of-action centred design. We will conclude by considering the process of "practice of course-of-action analysis" itself as a collective - interlinking of courses-of-action.

1. THE ENACTION PARADIGM AND ITS CONSÉQUENCES FOR TASK ANALYSIS AND DESIGN

For [25], as for nearly everybody since the criticism of behaviourism : "intelligent behaviour presupposes the faculty of representing the world in a certain manner. In this way cognitive behaviour can only be explained if we assume that an agent reacts by representing the relevant elements of situations in which he finds himself. Insofar as his representation of the situation is correct, the agent's behaviour will be adequate, other things being equal".([57], p. 37)

But [25] adds a hypothesis concerning this representation that can be formulated as follows : "cognition consists of acting on the basis of representations of a predetermined exterior world that have a physical reality in the form of a symbolic code in a brain or a machine" (ibidem, p.38). It is this hypothesis that is the basis for the "computer paradigm of cognition". According to Francisco Varela, this is the weak point : "the principal dissatisfaction that is at the origin of what we call here the enaction approach is simply the complete absence of common sense in the definition of cognition up to now. For cognitivism, as for current connectionism, the evaluation criterion for cognition is always the adequate representation of a predetermined exterior world. We talk either about elements of information corresponding to properties of the world (like forms and colours), or well-formed-problems solving that involve such a bounded world. However, our everyday cognitive activity reveals that this image is far too incomplete. The most important faculty of all living cognition consists, in a large measure, in asking relevant questions which arise at any moment of our life. These are not predefined but enacted, we make them emerge on a background and the criteria of relevance are dictated by our common sense in a manner which is always contextual." ([58], pp. 90-91). Besides, Simon himself had specified that : "in real life, there is no well defined, unique, and static problem but rather one which is constantly changing, whose definition is modified on the basis of information that the agents extract from their memory or they obtain through responses from their environment, to the actions that they have executed" ([42], p.239). Based on such evidence in empirical studies, the "course-of-action analysis" has therefore detached itself from the "computer paradigm of cognition" in favour of the "enaction paradigm of cognition".

In course-of-action centred design, the centrality of the analysis of real operators' courses-of-action in real work situations is due to profound theoretical and epistemological reasons concerning the nature of human activity and the possibilities in its scientific knowledge. The cluster of theoretical hypotheses at stake is that human activity is **autonomous**, i.e. consists of asymmetrical interactions between the agent and his environment, in the sense that his interactions concern not the environment as an observer from the outside could apprehend it, but his "proper domain", i.e. what, in this environment, is relevant for the internal structure of this agent at the instant t ; **cognitive,** i.e. manifests and continually develops knowledge ; **embodied**, i.e. consists of a continuum between cognition, action, communication, and emotion, to keep temporarily common sense notions ; **dynamically situated**, i.e. always appeals to resources, individual as well as collectively shared to varied degrees, which stem from constantly changing material, social, and cultural circumstances ; **indissolubly individual and collective**, meaning that even individual events are interwoven with collective events ; **cultured**, i.e. inseparable from a cultural situation that is either collectively shared or individual to various degrees ; and finally, **experienced**, i.e. more precisely causing experience for the agent at the instant t however partial and fleeting it might be.

These theoretical hypotheses are to be taken in their strictest sense. For instance, in contrast to various attempts made since the public **rise of situated action** in [44], the dynamically situated character of the activity cannot be reduced to the much anterior good methodological idea of making scientific studies of the human activity in non-experimental situations (see for example. the anthropological field studies and [27] quoted above). It is more the idea that firstly, the experimental situations are doomed to miss essential phenomena of human activity - at least if it develops unconnected from the scientific research in non-experimental situations -, secondly, the theories and methods for studying human activity in experimental situations ought to consider also its situated character, even if it might only be to justify the reductions operated. For instance, recognising the cognitive character of the activity does not just mean stating the trivial fact that man thinks, it is to affirm, contrary to various scientific approaches in the "Social Sciences", that it is essential to have notions concerning knowledge, its manifestation and development so as to describe, understand and explain this activity.

These theoretical hypotheses manifest the enaction paradigm in the work analysis and more generally in the analysis of everyday human practices. They have important theoretical and epistemological consequences. They imply distinguishing two phenomenal or descriptive domains of the agent's activity : **the domain of structure** susceptible to an operational description ; the **cognitive domain**, or the **domain of structural coupling** susceptible to a symbolic description. They respond to the formula : **domain of structure = that of the processes that lead to the cognitive domain**, with feedback at any moment from the cognitive domain to the domain of structure. The first domain concerns what we have just called the **"parts" of this agent**, in particular the interactions between the central nervous system and the agent as a whole, the second concerns the asymmetrical interaction between this agent and his environment. If neuroscience approaches concern the articulation between the two phenomenal domains, it is within their epistemological limits that make them "incapable of satisfying the necessary level of detail for the ontogenetic and phylogenetic explanations" [58]. The "Social Sciences" of which some psychological aspects are a part, can legitimately concern uniquely the cognitive domain. However, to ensure that their descriptions of structural coupling have a explicative value and not only a practical advantage, they must, first take into account the autonomous character of the agent that we have defined above, and second be considered, within the neuro-physiological knowledge of the moment, as summarising the processes that constitute the domain of structure. This, to evoke Varela's formula, is what makes these descriptions **admissible**. From this stems an epistemological problem that would be insurmountable now - and in the likely future for a reasonable period in the context of the neurosciences - if there were no other phenomenal domain, and which is the object of the second idea, and linked to the latter characteristic of human activity stated above, which is to be experienced, to give rise to an experience at every moment for the agent.

The "course-of-action analysis" does in fact add the consideration of this third phenomenal domain : the **domain of experience**, i.e. that of the agent's **course-of-experience**, of the constructing process of this experience at any moment, and takes an interest in the articulation between the cognitive domain and the latter. On the one hand, the knowledge of this course-of-experience for the agent is interesting in itself. Here we join the current thinking on "phenomenological naturalisation" (see [29]). It could also be said, though, that the appeal made in [25] for the "thinking aloud all along the problem solving process" does in fact inaugurate a systematic description of this domain of experience, but in our opinion, in thinking erroneously that "the processes posited by the theory presumably exist in the central nervous system, are internal to the organism" (op. cit, p. 9), when they concern the asymmetrical interactions between the organism and its environment. On the other hand, we make the hypothesis that the description of the course-of-experience, if it is correct, constitutes a description of the structural coupling that is partial but admissible. From these considerations stems the following formulas : firstly, **cognitive domain = that of the**

processes that lead to the domain of experience, hence enabling to contribute to the explanation of the latter, with feedback at any moment from the domain of experience to the cognitive domain, secondly, **description of the domain of experience = key, considering the actual limits of the neuro-sciences, to an admissible description of the structural coupling**, by means of an epistemological principle, that of the **primacy of the intrinsic description of the course-of-experience (domain of experience)** on that of the **structural coupling (cognitive domain)** as a whole, or more briefly, "**primacy of the intrinsic**".

These different formulas define levels that concern the agent-environment system and not only the agent himself and which are foreign to any separation between "mind" and "body". From these formulas stems the theoretical object that we have called "**course of action**", concerning the relation between the domain of experience and the cognitive domain, defined as follows : what, in the **observable activity** of an **agent in a defined state**, actively engaged in a **physically and socially defined environment** and belonging to a **defined culture**, is **pre-reflexive** or again **significant to this agent**, i.e. **presentable, accountable and commentable by him at any time during its happening to an observer-interlocutor in favourable conditions**. In this definition, the essential elements ("observable activity", "agent in a defined state ", "defined physical and social environment", etc.) have been presented in bold. The course of action is the agent's course-of-experience (also said to be "intrinsic organisation of the course of the action") and the relations it has with the relevant characteristics (said to be extrinsic) of his observable activity, of his state, of his situation (including other agents and partly shared by these other agents) and of his culture (partly shared with other agents), characteristics that are released by an interpretation of data about them according to the principle of the **primacy of the intrinsic** presented above. Hence, the following schema of the description of the course-of-action :

> **Description of the course-of-experience + observational data of the activity, of the agent’s state, of his situation and of his culture Admissible description of the relations between the dynamics of the constraints in the agent’s state, in his situation and in his culture, that of the structural coupling as a whole and that of the effects on the agent’s state, on his situation and on his culture**

Such a description of the course-of-action is documentable in natural work situations or more generally in practical everyday life. It is explanatory and leads, as we will see when presenting the "course-of-action centred design", to ergonomic recommendations concerning the design of situations, taking into consideration the characteristics of the agents' state (permanent and instant, physiological and psychological) and their culture.

For example, in a series of studies of car driving aimed at designing advanced assistance systems [63], taking into account the construction of the driving action in the situation, and considering action and perception as inseparable in this construction, our approach gave priority to the study of drivers' activity in a natural driving situation as a basic condition for understanding the complex and dynamic character of the driving activity and its eminently contextual dimension. We assumed in fact that driving is largely created as a function of circumstances which are never possible to fully anticipate and constantly changing. In addition, driving is multi-sensory and the driver is also almost permanently interacting with other drivers. In order to take into account all these characteristics and the construction of driving in connection with a given situation, we felt that it was essential to put drivers in real driving situations and to consider their point of view on how they carried out the activity, in order to collect “explanatory” data on it. These studies were mostly field studies on the open road during which a combination of quantitative and qualitative data were collected in connection with these general characteristics of the driving activity. For example, we were very systematic in collecting data on the dynamic of the vehicle and of certain other vehicles with which the driver was interacting (speed, acceleration, use of the brake, deceleration modes, combinations of speeds used, etc.), on the behaviour of the driver (manoeuvres, positioning in traffic lanes, action carried out on the vehicle and/or particular equipment, etc.), and on the context encountered by the driver (traffic, infrastructure, manoeuvres of other drivers, etc.). Secondly, we also collected data in connection with the characteristics specific to the particular dimension of the activity for which we wanted to provide assistance. It was thus possible to collect data on lateral veering or the immediate repositioning of the driver in his lane of traffic in the context of a study conducted for the design of a "Lane Keeping" type system. Relative speed and relative distance data were collected more particularly in the context of studies on management of speeds and distances. Similarly, data on distance in relation to an obstacle or another vehicle were collected more specifically for studies looking at how manoeuvres are carried out. In all cases, important emphasis was given in the studies that we conducted to the point of view of the driver himself on his activity, as an access to his involvement in the driving situation. This emphasis took the form of collecting verbal data while the activity was actually being carried out and/or in a self-confrontation situation (the driver watches a film of his journey, the latter being systematically recorded, and comments on it to clarify his actions and events). As it is clear from the kind of data collected, the car driver’s course-of-action was thus considered in all the dimensions which are present in the definition above.

If, contrary to these car driver's course-of-action studies we only consider the part of the agent's observable activity that is pre-reflexive, without taking any interest in other aspects of the observable activity, we will obtain a less developed description - but which is still interesting where empirical knowledge is concerned, and often sufficient for the design - of the structural coupling of this agent and his situation. It is often on this description, that we could qualify as minimal that the course-of-action centred design recommendations have been founded until now. Such a minimal description can explain extremely detailed phenomena. For example in a study of the course of action of agents for an assurance company carrying out a complex execution for the refunding of sickness files, it has been possible to show that each change in gaze direction towards the computer screen and the document (and of course towards the keyboard) could be precisely presented, accounted for and commented by the agents [33].

This is the case, to state just one example, in a study of the courses-of-action of railway traffic control that has been carried out in connection with designing a more computerised and more automatic control system [8]. We made audio-visual recordings of the controllers' behaviour and audio recordings of their verbalisations in self-confrontation but, in the analysis, the behaviour was reduced to elements that correspond to the controllers' verbalisations. For instance, no tentative was made to implement the tools of analysis developed by ethnomethodology and conversational analysis in order to understand the subtleties of human-human interactions, both verbal and gestural. The identification of typical traffic control situations, the systematic study of the controllers’ anticipating structure, the analysis of the difficulties in mutual comprehension with their interlocutors (controllers from other sectors, foremen, station masters, etc.), and of the processes of situated problem solving, which have been enabled through this reduction in the analysis, proved very important for design.

It is worth while noticing that it is regarding these relevant characteristics of observable activities, agents’ state, situation and culture, that the ergonomic interdisciplinarity in which these studies have developed, reveals its necessity. What the description of the course-of-experience gives is, on one hand a partial but admissible diachronic and synchronic description of the structural coupling, and on the other hand an orientation towards the relevant characteristics of the observable agent’s activity, state, situation, and culture. This is a lot, but not enough. New hypotheses need to be added, from the most general to the most particular ones, not discarding any possible contribution from other research in other scientific or technological disciplines.

It should also be remarked that the characteristic of autonomy can concern not only an agent and "parts" of this agent, but also an agent with his prostheses. Nevertheless, the consideration of the relative autonomy of an agent with his prostheses is not fundamentally different to that of the autonomy of one agent and brings us back to the latter.

2. THE OBSERVATORY OF COURSE OF ACTION AND ITS "RUDIMENTARY THEORY"

The data in [25] are simultaneous verbalisations, qualified as "thinking aloud". As a response to several critical articles, [10] and [11] have introduced a fundamental idea : "to end this confusion, we must extend our analyses of the tasks that our subjects are performing to incorporate the processes they are using to produce their verbal responses. The expansion of theories to include a theory of the measuring instruments is common place in physics. Experiments that involve weighing objects require at least a rudimentary theory of the pan balance. In the same way, experiments that record verbal responses of any kind need at least a rudimentary theory of how subjects produce such responses… Nor does this requirement of a theory of the response mechanisms involve us in a vicious circle. Such a theory must be developed and tested simultaneously with our theories of task performance." ([10], p. 216).

The "rudimentary theory of how subjects produce such verbal responses" that they put forward is based on a theory of memory storing, which today is very much called into question to the benefit of theories of reconstructing memory and the role played by interactional and social contexts in this reconstruction (see, e.g. [9], [37]). If today, we can take for granted most of the arguments Ericsson & Simon established to reject "the notion that verbal reports provide, perhaps, interesting but only informal information, to be verified by other data" set forward by Nisbett & Wilson ([11], p. 3), we ought to consider these verbalisations and the methods to obtain them in other terms than just memory storing and thinking aloud without consideration of interactional and social contexts.

This is why the course-of-action analysis is based on an **observatory**, different to that of Ericsson & Simon, in particular not just reduced to verbal data, and of which the "rudimentary theory" is evidently different. This other rudimentary theory comes from cultural and cognitive anthropology (concerning the mastery of the interaction between analyst and agent), from clinical and experimental psychology, from neuro-psychology (regarding recall and getting aware), from the study of private thinking developed by Pierre Vermersch and his colleagues (in particular concerning verbalisations in self-confrontation), and of course from methodological experience constituted in the tradition of the study of the course-of-action. It is made with supplementary hypotheses that cannot be validated (or falsified) by data produced in this way. This observatory thus being more complex, its diverse aspects are also susceptible to evolve in an unequal manner with the progress of researches, other than those solely focused on the courses-of-action themselves. Of course, amongst these other pieces of research there can be research on the course-of-action of verbalisation of courses-of-action. The latter have only been undertaken recently. The rudimentary theory of this observatory allows to precise the material conditions of situated recall (time, place, material elements of the situation), the follow up and the guiding of presentations, accounts and commentaries by the agents as well as the cultural, ethical, political and contractual conditions that are favourable to observation, interlocution, and creation of a consensus between the agent and the observer-interlocutor.

An articulated set of data collecting methods

A methodology has been developed to collect data on the courses-of-action that interferes as little as possible - or at least in a well-ordered way - in the development of the course of the activity at hand and that establishes necessary favourable conditions for observation and interlocution. It connects in a precise way, depending on the characteristics of the activities and situations to be studied, **continuous observations and recordings of the agents' behaviour**, the **provoked verbalisations of these agents in activity** (from the "thinking aloud" for the observer-interlocutor to the interruptive verbalisations at privileged moments judiciously chosen) and the agents' **verbalisations in self-confrontation** with recordings of their behaviour, the agents' **verbalisations in private thinking interviews** [61], where they are put back into context by strictly appealing to a guidance of their sensory recall. These kinds of provoked verbalisation aim directly or indirectly at making the pre-reflexive phenomena of activity appear. Other kinds of verbalisation, made by agents during activity analysis (called **second degree self-confrontation verbalisations** to stress the fact that they are situated in the continuity of self-confrontation proper) are also implemented. Here the agents are in the position of observers and analysts and their verbalisations constitute, not data, but **agents' contributions to the analysis of their activity.** In addition to these different types of data, there is the **"objective" data** (i.e. from the observer's point of view) : static or dynamic data on the agents' state, on the characteristics of diverse components of the situations (e.g. the prescribed "tasks" and organisational roles, the existing interfaces, the workspaces, the operating devices, but also the organisation of training, the management modes, etc.) and of the cultures (general culture, work culture, local culture, or family and personal cultures).

The implementation of these different methods in a particular work situation necessitates a **mutual familiarisation amongst agents and the observers-interlocutors**, analogous on a number of points to the classical ethnographical inquiry, which constitutes the central point in the preliminary study. But the latter has also as object to specify the aims and methods of the study and, more generally, a collaboration contract with the agents. Despite the riches of these data, the study of the courses-of-action and their collective interlinking should appeal, as in historical studies, to the "rétrodiction" (French term), i.e. the filling out through inferences the holes due to the limits of the data (see [60], concerning this notion that generalises the remark quoted in the introduction of [25] on the inferences to make in protocol analysis).

This observatory has and continues to borrow from other different approaches, but this borrowing is generally profoundly transformed in connection with the whole epistemological schema presented above. For instance, the **verbalisation methods in terms of "thinking-aloud"** of [25], which inspired us in 1979, have been completely reviewed, the **self-confrontation method** borrowed from von Cranach ([4] [5] [6] [7]) in 1983 has been completely reviewed in its implementation as well as in its aim, the **methods of field cultural anthropology** have been assigned the role of contributing to the realisation and the interpretation of observational data and of simultaneous, interruptive and self-confrontation verbalisation data, and finally the **observation methods of behaviour, of the agents' state, of their situation and of their culture** contribute to the modelling, not directly, but by the intermediary of the modelling of the course-of-experience. The **method of private thinking interview** which, contrary to the pervious ones, is linked to a theoretical construction fairly coherent with that of the course-of-action one [61], was assigned a limited role complementary to self-confrontation. If the use of video in self-confrontation, does favour the situated recall of the details of action, as well as perceptions and interpretations that have accompanied it at a given moment, in periods that can be long, it is unfavourable indeed to the expression of what has been constructed through sensory modalities other than vision and audition and the expression of emotions. The private thinking interview lacks the advantage of the video prosthesis but goes beyond these limitations. It is, however, worth noticing that, in research on sport performance at an international level (see [40] and [41]), the self-confrontation verbalisations of these exceptional individuals make some of these other sensory modalities become visible in a significant way, in particular touch and proprioception, as well as feelings (emotions significant for the agent).

Duration and articulation of data collecting periods

The systematic data collecting by the methods that we have just exposed takes time, in addition to which should be considered the time for re-transcription. In particular, it takes up expert time, as it is difficult for an expert in the course-of-action study to have these data collected and transcribed in totality by others less expert than himself. Many methodological choices require a personal familiarisation with the situation and should be done during the data collecting and the transcription.

The reflection on the duration and the articulation of the data collecting periods can be concentrated on the observed and recorded data. On one hand, the data of provoked, simultaneous or interruptive verbalisation are collected at the same time as the observed and recorded data. On the other hand, the time for self-confrontation, and extrinsic description data collection depends on the duration of the observed and recorded data collection.

The overall duration for the observed and recorded data collecting periods depends upon the time each continuous period takes, the spread over time, and the articulation of these periods, the number of these periods or articulated series of periods. This duration of the data collecting, hence the duration of their transcription depends on several factors : (1) the particular characteristics of complexity and variety of the courses of action, the agents, and situations taken into consideration ; (2) the particular temporal characteristics of the courses of action taken into consideration ; (3) the theoretical and/or practical aims of the study ; (4) the time constraints of the study, imposed e.g. by an outstanding design process ; (5) the competencies (general and in connection with particular characteristics of the courses-of-action taken into consideration) of the course of action study expert. These factors have to be considered in each particular study. It is difficult to state any general principle. We will consider the time pressure in the study as well as the competencies of the expert in course-of-action study, after having specified the design process itself, when we will tackle the quick data collecting and analysis (section 10). Here, we will insist on the temporal characteristics of the particular courses-of-action that are taken into consideration and we will also state and illustrate a **general principle of duration and articulation of data collecting periods**.

This general principle aims at documenting the elements of the **course-of-experience**, the **observable activity** and their **constraints and effects** on the agents' **state**, **situation** and **culture**, that are relevant for the design project. Implementing this principle therefore depends on previous hypotheses on the courses-of-action and the range of the design project. These hypotheses stem from former research in course-of-action analysis and course-of-action centred design, and from preliminary study. They enable to define in each case considered which is the **minimal articulated series of data collecting periods** to implement. The research that has enabled to state this principle can be considered as an application of this same principle. The best way of illustrating this principle is to present some research examples.

Activities related to discrete tasks (e.g. : [32] ; [33] ; [62] ; [63] ; [13] ; [2]).

All these research examples aim essentially at software-design as a central element in a support situation. In this case the solution is simple : the data collection can be organised on the basis of the treatment of a completed inquiry questionnaire, sickness file, information retrieval request, client's phone calls etc., within a larger context. The case of computer assisted telephone encounters, studied within a project for improving situations that were already existing [2], is essentially similar to the case of activities related to discrete tasks. Many questions concerning the software and the general support situation design can be approached by taking a client's phone call as a unit of data collection. However, some clients' calls and calls initiated by the agent to the different services in the company are organised in stories that can last for several hours or more. If, from this point of view, we want to redesign the software, and the company internal communication media, larger units must also be considered, for example a working day.

Activities of traffic control (e.g. : [17] ; [22] ; [12] ; [53] ; [54]; [8])

In air traffic control ([17], [22]), the significant unit of course-of-action, which is vital to know for the design of the interface and the training, is the follow up of a configuration of airplanes in a control district, i.e. of a series of airplanes maintaining different interdependent and conflictual relations (often reduced to a conflict between two airplanes, or just to one out of the entire current traffic). These follow ups of a configuration of airplanes can last for ten to twenty minutes. Therefore, the minimal period of observed and recorded data collection to be analysed can last for half an hour or an hour, surrounded by two half hours that enable to know under which general conditions the traffic took place during the half or full hour considered.

Collective recovery from breakdowns or chains of incidents (e.g. : [18] ; [19] ; [55]).

If we aim at the knowledge of the course-of-action of diagnosis and repair of breakdowns or chains of incidents in order to design a support situation for this diagnosis and repair, of course the data must be collected during the whole diagnosis and repair, alongside larger data that enable to specify the larger context. As these breakdowns and incidents happen unexpectedly (except in the case of experiments in natural situations concerning breakdowns or events benign enough to be provoked, see [24]), the observer is obliged to spend quite a lot of time ”waiting for the incident or breakdown”, which requires some courage, and a serious involvement on the part of the operators. Here we remark that many experiments in not realistic simulated situations are often justified in classical work psychology by this time spent waiting for the incident in natural situations. In the accidental control of a nuclear reactor ([19], [55]), as in the case of air traffic control already mentioned above, it is and has been possible – and even in the first case necessary – to study simulated situations on “full scope simulators”.

Activities with wide spatio-temporal horizons (e.g. : [20], [14])

The activities and communications of a wine grower [20] have very variable horizons, ranging from the realisation of a discrete task to the cultural year (or several cultural years for certain research-development actions), passing by the seasonal contexts. If the aim is a general improvement of the technical mastery of cultural novelties by the wine grower (e.g. by improvement of the documentation and the role of agricultural technicians), the periods of data collecting must join together these different horizons. In this study, therefore, data have been collected over the period of a year including (1) courses-of-action observations (combined with interruptive verbalisations), (2) the wine growers filling in time estimates and commenting on them everyday by phone for the observer during several three weeks periods and, more generally, (3) the use of different methods of the anthropological field study. The study of domestic energy control, within a design project for multi-access interfaces of control [14], resembles the first case but for more limited periods.

Training (e.g. : [64] ; [65] ; [23] , [47])

To know the transformations in the course-of-action during an on the job training process and thus dispose of a basis to improve the conditions of this job training, the data collecting should be done as in the first piece of research quoted, during periods spread over the whole training period, avoiding the provoked verbalisation methods that could modify the course of the training [64]. If, on the other hand, we are only interested in what happens during one session of training as in [65] and [23], the unit is the session and self-confrontation interviews can be used. Finally, as in [47], it has been possible to develop experiments in natural situations, where we concentrated the course of training on several successive journeys of the same traveller.

Activities of sport teaching, tutoring and training (e.g. [38], [39], [35])

These cases resemble the previous ones but the self-confrontation is permitted ([38], [39]), except – or with particular precautions – if the teachers or tutors are themselves on training [35].

Two other principles

Nevertheless, if we stay with the first general principle concerning the duration and the articulation of the data collecting periods and with the minimal articulation of data collecting periods that it enables to define, we could not take the variety of agents and situations into consideration. To ensure a sufficient degree of generality of the analysis, more data must be collected, focussing on agents and situations which are representative of the variety of the possible agents and situations. The minimum number of cases that can be considered is two, to eliminate the risk of inevitably taking a particular case as a general one, and to be able to formulate some hypotheses about the invariants and factors of variation. But of course this is not sufficient. We consequently have to add a complementary principle to the first, a general **principle of the generality of the analysis**. Its implementation depends on preliminary hypotheses about the variety of the agents and situations and depends much more than the implementation of the first principle on the particular purpose of the study and the temporal constraints involved. Finally, we join to these principles a general **principle for stopping (at least provisionally) the study**, considering the purpose of the study and the theoretical and methodological tools at our disposal, when the marginal gain of new empirical discoveries that are efficient in terms of knowledge and/or design made on the basis of new data tends towards zero.

3. THE PRIMACY OF THE INTRINSIC IN THE ANALYSIS

The systematic description of verbal protocols in abstract terms expressing hypothetical structural invariants is carried out by Newell & Simon in the form of a "Problem Behaviour Graph". Such a graph constitutes "a behaviour representation of subjects solving a problem in the laboratory" that "will retain the full information about the dynamics of search, including repetitions" ([25], p. 173). A requirement of their approach is to start with a "description of the task-environment by the experimenter" enabling this latter, in adding diverse considerations stemming from experimental psychology, "to construct a hypothetical problem space that is objective only in the sense that all of the representations that human subjects in fact use for handling the problem can be imbedded as specialisation of this larger space" (idem, p. 64). The authors themselves point out a difficulty in this approach : "the requirement can be satisfied approximately by studying situations where the complexity is great relative to the time available to subjects for analysing it. Then, the experimenter, even if he is no more intelligent than his subjects, can meet the requirement by devoting much more time to the analysis of the situation than is available to any subject (or alternatively, by withholding from them some of the information that is available to him about the structure of the environment). In the studies in this book ("Human Problem Solving"), we conform reasonably with this strategy for two of our tasks, cryptarithmetic and elementary logic, but fall short with the third, chess. We are, in fact, somewhat handicapped in studying the behaviour of masters and grandmasters in chess, since we cannot attain a better understanding of the task environment than such subjects »(ibidem).

Moreover, from the point of view of course-of-action analysis, a work situation - or more generally a practical situation - poses the same problem : the operator has an advantage to the analyst who only passes through - even if it might be for several months - : the advantage of time and practical know-how. Concerning work, such an analytical approach could only be reasonable if it might be considered a priori that the informations obtained in a limited lapse of time with the engineers, managers and operators, include all those which are used by the operator during the work period being studied. From this claim stems the development of an other method of analysis that has its starting point in the operator's activity and not in an a priori "task structure".

The **principle of the primacy of the intrinsic** is a principle of analysis. It makes no hypothesis whatsoever on a hierarchy of "causes". Rather it sets up a roundabout through the description of the course-of-experience in the search for "causes" in the agent’s state, his situation and culture. It only concerns the analysis and not the entire methodology. In particular, it does not say that it is essential to know the course of experience before collecting the data concerning the agent’s state, his situation and culture. We have seen above that the ethnographical enquiry, that firstly concerns the culture shared by the agents, is the centre of the preliminary study. To this might be added a preliminary knowledge of different characteristics of the agents and different technical characteristics of the situations, in particular the prescribed tasks. However, it is highly recommended, as a spiritual ascesis to persons used to an approach similar to that of Newell & Simon, to develop their knowledge on technical characteristics of situations, in particular the tasks, after having acquired further knowledge of the course-of-experience in itself.

This principle of the primacy of the intrinsic in the analysis entertains a relation with what the 20th century philosopher Edmund Husserl called "temporary suspension" of all “constituted”— scientific or common-sense — knowledge and of all practical interests in order to consider as freely and openly as possible an object together with the perceptive and cognitive activity through which it is constituted. What exactly does this temporary suspension consist of in course-of-action analysis ? Firstly, we have to, temporarily, systematically doubt the possibility of directly transferring to cognitive task analysis the scientific results obtained by considering situations other than the actual work or practice situations concerned, e.g. laboratory situations or interview situations outside the work or practice situation, or by considering separate aspects of the activity, e.g. problem solving alone or perception alone. In addition, in order to open the field of analysis as much as possible and minimise the possible constraints imposed on the analysis by the spontaneous ideology of the analyst, it is necessary to — temporarily, we must stress — suspend one's practical interests, even the most meritorious of them (course-of-action centred design interest in particular!). Then in the course-of-action analysis it is impossible to stay limited to an observer's point of view, if work activity is to be explained, thus contributing to transform situations in a scientifically founded manner. Finally, we must not take common-sense notions like 'intention', 'goal', 'sub-goal', 'task', 'sub-task', 'reasoning', 'planning', 'action', etc. as given. However, we are obviously not saying that this constituted scientific knowledge, these practical interests, this observer’s point of view and these common-sense notions are devoid of interest, but that the interest of a whole segment of them can and must be judged purely based on consideration for the work or practice activity. This is the reason why this point of view is very close to that of phenomenological reduction expressed in different ways, subsequent to Husserl, by all the followers of the phenomenological philosophy trend. Husserl always said that constituted knowledge, practical interests, observer’s point of view and common sense were not called into question by phenomenological reduction, but merely temporarily 'put between brackets' in order to develop them in new directions. This temporary suspension can—and this is important—make use of two symmetrical crutches : the practical constraint — the designers’ demand — helps in the suspension of constituted scientific knowledge ; the scientific-academic constraint—the need to both discover something new and thoroughly consult the literature, which could be related to the work situation considered—helps suspend practical interests and common sense. This temporary suspension also causes one to consider carefully the work analysis situation : the relationship in the work space between one (or more) agent who not only operates but also has his own point of view on his own activity and can express it, and an observer who not only observes but also can ask questions and — to a certain extent to be carefully specified — is capable of empathising. Whence the evidence from the point of view of the scientific observer can be called into question. The whole problem for the work analyst is then seen as follows : first of all, to possess theoretical notions, principles, and methods making it possible to describe and link the individual agents’ experiences together with his view from the outside, and secondly, to surpass and control the limits of his capacities as an empathising observer thanks to activity-recording tools, agent questioning methods, and theoretically founded methods. From this primacy of the intrinsic in the analysis stems the importance given to the theory of the course of experience that we will now present.

4. THE COURSE OF EXPERIENCE AS ACTIVITY-SIGN

It is due to this reversal of Newell & Simon’s approach operated by the principle of the primacy of the intrinsic in the analysis that the course-of-action analysis was led to focus on and solve several crucial description problems in the theory of these authors : the separation between perception-action and cognition description problem ; the multimodal and non-symbolic perception description problem ; the separation between anticipation and perception-action-cognition description problem ; the separation between emotion and anticipation-perception-action-cognition description problems. These four description problems are linked with a more embedding theoretical problem, the mind / body problem. The course-of-action analysis considers all the phenomena of interpretation, reasoning, perception, action, anticipation, emotion as both bodily and cognitive and describes them at a particular level that we will specify below.

The description of the data protocols of course-of-experience collected implements – and modifies more or less significantly in the case of a failure – a generic model of human experience, baptised « semio-logical framework », or « activity-sign » (notion inspired from the philosopher, mathematician and scientist, C.S. Pierce who spoke of « thought-sign »), obeying to a « phaneroscopy » (other notion of C.S. Pierce). The central notion of the description of the course of experience that we have proposed is indeed a notion of sign, qualified as hexadic due to the fact that it involves six essential components. This notion links, in precise structural relations, components that are supposed to summarise the concatenated processes at work in a unit of course of experience, i.e. in a unit of activity that is significant for the agent considered, whatever its duration might be (this is the reason why we can qualify it as fractal). It is in rupture, like the semiotic Peircean theory from which it was inspired given notable transformations, with the signifier/signified dyadic Sausserian conception of sign which presides over both cognitivist psychology and structuralist semiotics.

The fact that a notion of sign presides over the analysis of human activity, even limited to the course-of-experience, is not surprising if we recall some facts of the history of psychology and semiology : the notion of triadic sign of Peirce was already of this type, in connection with semiosis, the dynamics of signs as human activity ; the notion of dyadic sign of Saussure had already been interpreted with profit as concatenation of psychological processes (processes of production of the signifier/process of production of the signified or concept) ; L.Vygotsky had sketched out an attempt of treatment of human activity in terms of signs which has remained famous, even though it was not very fruitful empirically. However, the construction of the notion of hexadic sign has not been limited to the contribution of these authors. It has been made though the conceptual and epistemological contributions coming from diverse and varied disciplines : theoretical biology, cultural and cognitive anthropology, ethnomethodology and conversational analysis, linguistic pragmatics, psychology, psycho-phenomenology, theoretical semiotics, and theoretical semantics, semiotics of texts, « natural logic », philosophical phenomenology etc. In addition, these diverse contributions have been integrated into a coherent whole and did not emerge unscathed from this integration. Hence a conceptual vocabulary which testifies to numerous loans - which are more or less faithful -, and also to neologisms, in order to, on the one hand « embody » the sign, and on the other hand not to engender confusion.

The first version of the notion of **hexadic sign** emerged in 1997. It replaced that of “tetradic sign”, inaugurated in 1986 and which underwent several improvements over the course of empirical research and theoretical reflection. The last version of tetradic sign appears retrospectively as a useful simplification for the application of hexadic sign. The notion of hexadic sign describes the process of construction of a unit of course-of-experience, or **local construction** of the course-of-experience. This unit can be fairly large, provided that it is significant for the agent, but the more that it is elementary, the more its description in these terms is heuristically fruitful, at least if it is based on sufficient data. It links together six essential components – which correspond also to processes – and builds them thanks to meta-mathematical notions of relationships that we take here as established (see [49]) : monadic relation, dyadic relation, triadic decomposable and undecomposable relation; relation of thought, real relation which gives way, in contrast to the relation of thought, to the interaction of linked elements. These components are the following :

- **E : Involvement in the situation** = the principle of overall equilibration of the agent’s interactions with his/her situation at a given moment = the overall closure of possibilities for the agent at this moment, coming from his/her past course of action;

- **A : Potential actuality** = the varied expectations of the agent relative to his/her dynamic situation at a given moment = which, taking into account **E**, is expected (in a more or less determined way, passive or active) by the agent in his/her dynamic situation at a given moment, following his/her past course of action;

- **S : Referential** = the types, the relationships between types and principles of interpretation belonging to the culture of the agents that he/she can mobilise taking in account **E** and **A** at a given moment;

- **R: Representamen** = which, at a given moment, is an effective sign for the agent ("external", perceptive, or "intern", proprioceptive and mnemonic). **R** specifies **A** and **a/A**, i.e. in **a** on a background of **A**;

- **t*R : R assimilated** = an intermediary element (that we can count or not as a seventh element) constituted by the assimilation **t*R** of **R** by a type **t** belonging to **S**. It is a real dyadic relationship between **R** and **S**, hence the specification of **S** in **s/S** and transformation of **R** into **t*R;**

- **U: Unit of course of experience** = fraction of pre-reflexive activity. It operates a transformation of **E** and **A** and a specification of **s/S** into **tt/s/S**, i.e. in a relationship between types **tt** on a background of **s** on a background of **S**. Between **R** or rather **R** assimilated (**t*R**), **U** and (**E – A – s/S**), there is a triadic relationship decomposable into two real dyadic relationships in the sense that **U**, on the one hand depends on **t*R** and both develops it and absorbs it, and on the other hand depends on (**E – A - s/S**) and transforms them;

- **I : Interpretant** = construction, extension of the area and/or of the generality of the types and relationships between types through the production of **U**, and the completion of the transformation of **E, A, S**, into **E', A', S'**, which expresses the idea according to which human activity is always accompanied by some situated learning (or discovery).

A fundamental theoretical characteristic of these notions is that they are built one on top of the other. For example, the notion U supposes all the notions preceding it in the list here above, as well as the transformations carried out along this construction. A methodological characteristic is that these notions can be represented graphically, which allows the construction of graphs of concatenation of hexadic signs, each of them starting from a state of preparation (E, A, S) produced by the preceding sign and leading to the state of preparation (E', A', S') of the following sign. Such graphs correspond, given a radical change of paradigm and a corresponding development of the complexity, to the problem solving graphs built in more simple terms of states of information and of information processing operators by [25].

Concerning all these notions and the set of non-trivial theoretical hypotheses that they express and which specify the essential characteristics of human activity announced above, I will content myself with referring the reader to the published texts (see for example [49]). On the other hand, it seems necessary to insist on the characteristic of the approach that they express : what is called a litteralisation of the course-of-experience, i.e. the generation of hypothetical empirical consequences from the manipulation of symbols to which we attribute a content. This characteristic of litteralisation of notions and hypotheses is reinforced by the dependence of the construction of the hexadic sign relative to a more general category construction. The components of the hexadic sign emerge indeed respectively from six (seven) corresponding general categories, noted respectively 1.1., 2.1, 3.1, 2.2, 3.1*2.2, 3.2, 3.3, in order to insist on their formal character. These general categories are inspired, given a renewal of their construction and their interpretation, from the six general categories proposed by C.S. Peirce in one of his last essays concerning categories ("A guess at the riddle") and which constitute the heart of what he called "phaneroscopy" ("examination of the phenomenon") in order to show both its proximity and its relative distance to the philosophical phenomenolgy ("theoretical discourse on the phenomenon") of the philosopher E. Husserl. Peirce thought of his six categories as constituting descriptive categories of all possible phenomenon. Without specifying further the general categories that we propose, let us say just that they are by construction **descriptive categories of all interaction phenomena between an autonomous system whatever it may be and its environment**, whether it is possible or not to speak of experience of this phenomenon for the autonomous system considered. The interest for the analysis of the course-of-experience of these categories is due also to the fact that, with supplementary hypotheses of which certain have already proved fruitful, the different components of the hexadic sign can be categorised in their turn according to the same diagram of construction (that we cannot present here). For example, a unit of course of action U can be an **actual opening** (retaking, introduction or transformation of an opening[2] of the agents in the situation), a **multiplicity of feelings** (significant emotions for the agent), an **interpretative turmoil**, a **determination** (of an element object of attention), an **inference**, an **action** (which can be an ordinary action, an action on oneself, an action of search for information or an action of communication) or an **argument** (or symbolic construction of new types or new relationships between types). Just as each component of the hexadic sign supposes and integrates in its construction components which precede it in the list, each category of each of these components supposes and integrates implicitly in its construction the categories which precede it in the list. However, the definitions of the diverse sub-categories of the components of the hexadic signs which compose the current table of these sub-categories are not stabilised completely. A fortiori, their empirical validation and the test of their heuristic fruitfulness are unequally developed.

To illustrate this notion of sign, let us give an example of determination of the components of the hexadic sign using data, which comes from the analysis of the course-of-experience of railway traffic controllers in [8], the most recent study which was carried out in a design process:

We present the situation where the controller of post 2 (CCF P2) asks the controller at post 5 (CCF P5) how to transfer the train no. 147 between their respective control posts. The controller of post 5 informs his colleague that a foreman should occupy the northern line and, next, the southern line, but that he doesn't know when the northern line will be available. The two CCF discuss the situation and put off the decision concerning the transfer of train no.147. In addition, let us mention that the CCF at post 5 is put out by a signalman that he cannot get into contact with and whom he needs, to be able to direct the train no.310 which is coming onto his territory.

	CCF P5 : *Yes Antoine ?*
	CCF P2 : *XXX*
Unit 1 –	***CCF P5 :*** *Yes. In a moment I'm gonna lose…well there, behind 21, they are going to get out the machines on the North at Saint-Hilaire.*
	CCF P2 : *O.K.*
	CCF P5 : *They gonna travel up to Beloeil East with that, at the worst they gonna get down on the southern line, then they gonna change a long rail on the southern rail today.*
	CCF-P2 : *O.K. means we're losing err... X a bit XXX*
Unit 2 –	***CCF-P5 :*** *You're going to lose…. well the north is going to come back just when we're going to lose the south. Means that we're going to... all use the northern line today. But when,*

[2] We will define this notion of opening in the following section.

		I don't know!
	CCF-P2 :	*O.K. Well, you'll tell me.*
Unit 3	***CCF-P5 :***	*O.K. For the moment, wait before aligning the 147 for example*
	CCF-P2 :	*Yes, O.K. No rush..*
Unit 4 –	***CCF-P5 :***	*Err… well* [laugh] *no, there's no rush yet, but err...*
	CCF-P2 :	*No, there's no rush yet, it's not there, then, err… even if your guys … you see, they travel … they go up to Beloeil, or at the worst, they can drag themselves back to Beloeil. We're going to wait for them there.*
Unit 5 –	***CCF-P5 :***	*Err...it's because that would perhaps be the southern line … err, the line … err...yeh, well yeh, yeh, yeh.*

Let us consider the unit 3 of course-of-experience : "*O.K. For the moment, wait before aligning the 147, for example*." In contrast to the logical order according to which the components of the hexadic sign have been presented in the preceding section, we will follow, here the order according to which it is possible to document them, which starts with what is actual for the agent.

U corresponds to the verbal communication produced by the CCF of post 5 when he replies to the question of his colleague and the perception of the good reception of this communication. We see that, in this study, we have chosen not to consider the smallest possible unit of course of experience.

R includes both the question of his colleague in connection with the transfer of train no.147 and the recall of the unpredictable character of the place where the foreman will be when the train arrives on his territory. In order to document R, we have used his verbalisation in a situation of self-confrontation. Indeed, the CCF explains that: "[…] *our train was coming nearer. Then, the place where we could send our train was dependant hugely on what he was there to do; because I want him to work, that guy there*."

If the determination of **E** is trivial here (it's enough to say that **E** belongs to the category "practical involvement"), that of **A**, and in particular the determination of the openings which are the basis of the expectations of the controller, is essential for design. The openings documented are : the approach of train no. 310 which must take a switching liaison ; the signalman who does not reply to the radiotelephone calls of the CCF ; the occupation of the line by the foreman Després. Their documentation comesfrom the analysis of the course of action which precedes this particular moment, and from the verbalisation of the CCF in a situation of self-confrontation. We know, due to the analysis of the past course of action, that the train no.310, is approaching "his" territory and that "he" has to make a liaison switching by manual commands. This is why the CCF is trying to contact the signalman. In addition we know that the foreman Després has informed the CCF that he will occupy the line in the zone of the station of Beloeil. We also know that he will go first of all on the northern line in order to fetch his equipment at Saint-Hilaire and that next, he will go onto the southern line in order to change a rail. In addition, in a situation of self-confrontation, the CCF speaks to us, amongst other things, about the difficulty that he is experiencing in contacting the signalman ; he admits that that makes him nervous: "*See if he* [signalman] *makes me nervous due to that* ". Let us now look at the expectations which emerge from the openings of the CCF.

If we cannot pretend to have access to the set of the active and passive expectations of the agent, we can distinguish the following: the trains no.147 and 310 will arrive very shortly on his territory ; the foreman Després will go onto the northern line and then, will work on the southern one ; to give a circulation permit to train no.310 if the signalman doesn't show up. These expectations are documented in two ways : by the verbalisations of the CCF and by a confrontation of these verbalisations with the expectations and the openings linked to the units of course-of-action preceding the unit considered. As an example, let us take the situation of self-confrontation where the CCF says: "*I'll have to give his* [train no. 310] *permissions, and then warnings on the switchings so that he changes line*." In this case, we know that the CCF is preparing himself to give an authorisation to make the train no. 310 carry on if he doesn't succeed in contacting the signalman. In a second stage, the expectations inferred with the aid of the verbalisations will be confronted with the ones set out earlier.

We didn't attempt to describe **S** at each moment, though we sought to describe **s**, i.e. the types and the relationships between types mobilised by the agent in relation to **R**. We can, at least roughly deduce from this **S**, given a summation. When the CCF produces interaction unit no.3, we infer from the self-confrontation verbalisation that the CCF knows that he must not direct a train onto a line to transfer it, before being certain that the line in question will well and truly be available: "[…] *I tell him to wait before aligning the 147, because there, Després […] was not transferred there / his equipment was coming out of here* [between Bruno JCT and Douville]. *[…] Then at some point, he needs to go three or four miles over there, to take the liaison, to go onto this line here. But all that, it's not done yet. But our train was coming close. So, where we were for sending our train depended hugely on what he was* [the foreman Després] *doing*." In this way we documented the elements of **s** by inference using the verbalisation of the CCF and our previous knowledge of the activity. The types and the relationships between types named in this way were then validated in part by the CCFs.

I here is trivial. It is the simple reinforcement of the practical previous knowledge of the controller without any new contribution, even if it is potential

In relation to design, the direct value of this analysis in terms of hexadic signs is to specify the transversal aspects of the course of experience considered to be taken into account in the definition of interfaces, of space, of the communication tools and of the training of the various agents, as is shown for instance in [8], from which we extracted the last example above.

5. THE COURSE OF EXPERIENCE AS A LATTICE OF SIGNIFICANT STRUCTURES RELATED TO THE STRUCTURE OF ANTICIPATION AT t

The notion of **significant structure** has a history dating back to 1979. Its development started from research in semiotics and the grammar of texts, and from a difficulty identified in [25] : a systematic description of the protocols, second by second, (local description) to which a notion of "episode of problem solving" was added (global description) presented by the authors as a-theoretical, as purely methodological but which nonetheless participated in a significant way in the description and the explanation of the data.

The semiological framework as a whole can be summarised in the formula : **concatenation of hexadic signs = process leading to a set of significant structures,** with retroaction at each moment between this set and the processes which lead to it. These significant structures express continuities of creation, transformation and closure of **openings** $\mathbf{o}_i$, i.e. what constitutes the basis of the Potential actuality A, i.e. the anticipation structure at each instant. Reciprocally, the determination of these significant structures informs us about A.

In order to specify this notion of **opening**, let us consider control activities in a full scope simulator of a nuclear reactor control room. A property of the course of action of each agent is its opening to a more or less indeterminate future. This is why we detail the common-sense notion of occupation by introducing that of "opening". An elementary action can be fully completed : thus, looking at the simplest example, the agent makes a phone call, gets hold of the right person, and gives his message : "You're wanted in the control room." In this case, once he has hung up, the operation has been carried out and completed. On the contrary, if the agent makes a call and cannot speak to the right person, he leaves a message asking to be called back. In this case, when he hangs up, he creates an *opening* or, in other words, an action which has not been completed, which remains open to a future end. The same can apply in the first case too if there are other contingencies accompanying that of arrival of the person called, such as briefing him on the situation.

In fact, this notion of opening is a very general one. Its relevance extends well beyond cases like this. As soon as a simulator test begins, an opening is created for each operator and experienced by him : operation under normal circumstances that will be turned into an emergency operation, in one way or another. As soon as any operator gets involved in an emergency procedure, an opening is created : the situated follow up/ situated interpretation of the instructions, until they have been successfully accomplished or until the evolution of the process leads the operator to change procedure.

These openings, noted **o**, therefore the significant structures which express their continuity of creation, transformation and closure, maintain diverse relationships between themselves. First of all, for a given hexadic sign, the Representamen R leads both to the **selection of an o** and the **subordination to o of an** $\mathbf{o_R}$, concerning the extinction of the perturbation **R**, and **U** transforms, in **A, o in o'** (and possibly an opening $\mathbf{o'_R}$ if the opening $\mathbf{o_R}$ is not closed by **U**). In so far as **o** selected at instant t, is or not identical to the opening **o'** resulting from the preceding sign at instant t-l, there is **temporal continuity or discontinuity.**

Next, between the openings $\mathbf{o_i}$ and $\mathbf{o_j}$ selected by the Representamens of two different signs, there can be, from the point of view of the agent :

- **dyadic diachronic or serial relationship** : the openings $\mathbf{o_i}$ and $\mathbf{o_j}$ ($t_i > t_j$) are, from the point of view of the agent, at the moment t_j considered, the same except for the determinations contributed by the course-of-experience between instants t_i and t_j.
- **dyadic synchronic subordination relationship** (valid for a given interval of time) : $\mathbf{o_i}$ is subordinated to $\mathbf{o_j}$ if, from the point of view of the agent in this time interval, the extinction of $\mathbf{o_i}$ contributes to that of $\mathbf{o_j}$.
- **triadic synchronic contextual relationship** relative to a given opening (valid for a given time interval) : for the agent, the openings $\mathbf{o_i}$ and $\mathbf{o_j}$ are independent but both subordinated to an opening $\mathbf{o_k}$. Finally, all the openings at a given moment are in a triadic synchronic relationship relative to the involvement in the situation E.

The other sorts of relationships, that we will not specify here, are refinements and specifications of these three sorts of relationships. All these relationships can criss-cross and therefore don't necessarily produce trees, but eventually trees form, which rhizomatise and the rhizomes branch. Let us remember that, by definition, in a maximal rhizome, all nodes can be in relationship with all the others. These relationships build different sorts of **significant fundamental structures** that we cannot specify here : planned sequential successions (prospective or retrospective), serial successions, synchronic subordination successions, contextual synchronic successions, sequences, macro-sequences, series, synchrones, etc. The analysis in terms of significant structures of a particular course of experience, such as the analysis in hexadic signs, gives rise to a representation in the form of a graph. Such graphs express the sequentiality, the parallelism and the hierarchical subordination of significant structures. By construction, the descriptions executed in terms of hexadic signs and in terms of significant structures are dual.

The value for design of the determination of these significant structures is that their comparison allows to identify **archetypal structures** which provide corresponding scenarios for design. In this way, the analysis of railway traffic controllers' courses-of-experience, already quoted [8], enabled us to identify the following archetypal series : organise and co-ordinate the circulation of trains, locomotives and maintenance vehicles; co-operate in the transfer of trains between territories; respond to demands of occupation of the line. For each of these archetypal series, it also enabled us to identify sequences or complementary or alternative macrosequence archetypes which compose them.

6. COLLECTIVE INTERLINKING OF THE COURSES OF ACTION

Another theoretical and description problem concerns the relationship between individual and collective cognition. Indeed, « Human Problem Solving », due to its theoretical postulates, aims at studying the « human system of information processing ». Hence a scientific approach which separates the individual from his fellow men/women. Therefore it has been possible to qualify this scientific approach and its extension in the « cognitive task analysis » as « methodological individualism. »

As the work activity – and more generally the practice – has by nature a collective aspect, several solutions have been attempted. The first one, the most prevalent and the laziest, has been to consider that the collective activity constituted a superior level to that of individual activity, having the same structure. The second one has been to consider that individual activity could only be described and explained by way of a description and explanation of collective activity. This is the classical interactionnist approach inspired by ethnomethodology (e.g. [15]), to consider, amongst the numerous pieces of research of this sort, one of those which contributed significantly to our own studies concerning traffic control) and also the "socially distributed cognition" approach [16], that we could qualify as "methodological collectivism".

The course-of-action analysis constitutes a middle-way between methodological individualism and methodological collectivism, which can be coined as " methodological situationism ", thanks to a better definition of the levels of analysis allowed by the enaction paradigm and a consideration of both co-operation and antagonism between individuals.

The characteristic of autonomy does indeed concern, more than just the **agent** himself, the **agent with his prostheses** and **"parts" of this agent** which we mentioned earlier. It concerns also a **collective of agents with their interfaces.** In order to consider this characteristic of the autonomy of a **collective of agents with their interfaces,** i.e. to study it as such and also to draw from this study consequences for the design of collective distributed situations, another theoretical object is considered, partly inspired by the afore mentioned approaches, the **collective interlinking of courses of action**, according to the formula : **intertwining structural individual couplings** (identified according to the principle of the primacy of the intrinsic) = **processes leading to the collective interlinking of the courses-of-action**, i.e. to the structural coupling between a collective with its interfaces and its material and social environment, with retroaction at any moment of this collective interlinking to the processes which lead to it. If the course-of-action is individual-social and enables us to consider the collective from the point of view of a given individual, the collective interlinking of the courses of actions is **social-individual**, and enables to consider the collective as such, though not forgetting that it is the product of courses-of-action. Let us specify that a collective is not a given fact and that one and same agent can participate in parallel, in diverse collectives which are more or less wide and persistent.

However, the constructivist paradigm does not exclude direct study of it, i.e. without going through study of individual-social activity. A study of the collective construction of the activity can give rise to more parsimonious theoretical objects and observatories than the study of courses of action which sacrifice phenomena of the individual construction of the activity to acquire easier access to its collective construction. As we show in [50], where, concerning a fragment of data of nuclear control in accidental situations, we compare a " socially distributed cognition " analysis with a collective interlinking of courses-of-action analysis limited, in relation to observable activity, to the part of it belonging to the course-of-experience of the different agents (see section 2), the phenomena sacrificed in the first approach do not prevent explanation concerning some parts of the activity, but do concerning some other parts.

Were we to leave things there, the interactionist studies and studies of “distributed social cognition” would simply appear to be more parsimonious and therefore faster approaches that are more limited than such studies of collective interlinking of courses-of-action, but which are sufficient in certain cases and for certain aspects of the activities. In fact, these interactionist studies and studies of “distributed social cognition” also consider relatively subtle phenomena of spoken and gestual interactions, as for example [15] points out, which are not appreciated by the collective interlinking of the courses of action, at least when limited, in relation to observable activity, to the part of it belonging to the courses-of-experience of the different agents.

In all, we feel that in the current scientific context of abandonment of the “computer image of mind” (or paradigm of “man as an information processing system”) in favour of the concept of cognition as embodied, situated, cultured, and indissolubly individual and collective, the course-of-action analysis, the interactionist approach, and the “distributed social cognition” approach, in conjunction with other approaches - which it is not our purpose to list here - are building the various facets of what could be called cognitive anthropology or empirical praxeology and the methodology for the corresponding design. A part of the results and methods of these “ methodologically collectivist ” approaches can certainly be integrated in a fully developed course-of-action analysis. But, as such an integration is not effective for the moment, the co-operation of a plurality of these approaches seems to be the right way forward.

It is not possible here to give sufficiently developed examples of studies of collective interlinking of courses of action which have been carried out. Let us just say that, in certain cases, collective activity can be considered as being that of a collective agent. This was the case in the study of activities of diagnosis and repair of computer software breakdowns in an insurance company [18] due to the fact that these activities involved agents whose competence was similar faced with the same computer screen. Such a reduction was on the other hand not relevant concerning the metropolitan traffic control which involved a dozen controllers and signalmen, with diverse competencies and roles and equipped with slightly differing computer interfaces. The analysis of collective interlinking of courses-of-action has essentially consisted of analysing, in parallel, the individual-social courses-of-action of two controllers, and one controller and one of the signal men who were associated with him and to identify the relationships between the diverse fragments of these ([12], [53], [54]). Concerning accidental nuclear reactor control on a full scope simulator, we needed to proceed in stages, both due to the difficulty of the analysis and to the complexity of the data to collect and analyse – and therefore also the difficulty to convince the management of the value of these. We went from a first analysis of fragments of the courses-of-action of reactor operators [19], to a first analysis of collective interlinking of the courses-of-action of the supervisor and the reactor operator carried out on the model of the study of metropolitan traffic control, then to a second more developed analysis, concerning the same agents with the same data [55], and a preparatory study of a wider study concerning the supervisor, the reactor operator and the water-steam operator. These various analyses also give way to graphs which link the elements of the situation and the agents’ courses-of-experience, in terms principally of significant structures but also secondarily in terms of hexadic signs [50].

7. ANALYSIS, MODELLING AND FALSIFICATION

As mentioned above, the notions represented in the "Problem Behaviour Graph" of Newell & Simon are those of "*information processing operator*" and "*state of information*". We must add here that the "*information processing operators*" are next analysed in *productions,* i.e. in expressions of the form "condition   action" composing a "production system". The whole analysis can then be summarised in the search for a translation of the whole of the protocol in terms of these productions. "The failure to find a production (or sequence) that fits a segment of protocol has various causes, ranging from lack of data to inability to construct an appropriate mechanism" ([25], p. 203). It is therefore a case of evaluating these causes and, for the failures which do not seem to stem from the lack of data, to look for " a modification of the production system " which is successful (idem, p. 209). The epistemological problem of this approach is that the falsification by the empirical data is therefore susceptible to put into question only the concrete use of the theory and not the theory itself. The course-of-action analysis also searches systematically the falsification of its descriptive notions by data, but, on the contrary, uses systematically this falsification in order to develop the theory.

This requirement for a scientific approach added to the particularity of the theoretical objects studied (ontology), leads to putting a lot of care into specifying the epistemology of the study of courses-of-action and their collective interlinking, in matter of the observatory as we saw in section 3 and in matter of the modelling as we are going to see in this section. In particular, we make the following distinctions : distinction between the analytical empirical model (of the course-of-experience, of the course-of-action or of the collective interlinking of courses-of-action) and the synthetic empirical model (of the course-of-action or the collective interlinking of courses-of-action), between the synthetic empirical model and the synthetic practical model, between the synthetic model of diagram type and the synthetic model of simulation type.

Modelling allows, on the one hand to benefit from the gains in connection to precision, fruitfulness and validation/falsification of hypotheses which allow the litteralisation of the latter, and on the other hand and complementarily, to contribute to technical transformation. It is taken here in its strictest sense, in which the model is inseparable from theoretical objects, empirical data and theories.

The analytic empirical models of course-of-experience

The analytic empirical models of course-of-experience are shared between two poles:

- **models of local construction** of courses of experience studied, i.e. models which take into account the underlying organisation of the significant units of the corresponding courses-of-action. The highlighting of these signs underlying the different significant units constitutes by hypothesis a means to understand how the significant units build up and interlink. The hexadic sign hereby constitutes a very general and abstract model - a **generic model** – of the local construction of the courses of action which, by hypothesis, is relevant for all possible courses-of-experience. This generic model enables to guide the development of more specific and concrete analytical models – **specific models** – of local construction of particular courses of experience.
- **models of global construction** of courses of experience studied, i.e. models, that take into account the different significant units, which compose the corresponding courses of action, their concatenation, their arrangement. The fundamental significant structures, of which the principle of construction has been introduced above constitutes a very general and abstract model - a **generic model** - of global construction of the courses-of-experience. These fundamental significant structures did indeed prove relevant for the analysis of the construction of courses-of-experience as diverse as those of information-retrievers, administrators of computer networks, winegrowers, etc. They enable to guide

the elaboration of more particular and more concrete analytical models - **specific models** – of global construction of such specific courses of experience.

But in general we are lead to construct **mixed local/global models**. This has been the case in the study of railway traffic control, that we have already presented earlier, but also in the study of nuclear accident control and of international competitions of table tennis, two other recent studies [41].

These various models of courses-of-experience lead onto **analytical models of courses-of-action** of which there exist no generic models, due to the fact that the relevant characteristics of observable activity, of agents' state, situation and culture are very variable depending on a lot of heterogeneous factors.

8. COURSE-OF-ACTION ANALYSIS VERSUS EMPIRICAL AND DESIGN SYNTHESIS AND THEIR CONNECTION WITH THE OBJECT OF COURSE-OF-ACTION CENTRED DESIGN

According to [25] :

- « The present theory is oriented strongly to content. This is dramatized in the peculiarity that the theory performs the tasks it explains. That is, a good information processing theory of a good human chess player can play good chess ; a good theory of how humans create novels will create novels ; a good theory of how children read will likewise read and understand. There is nothing mysterious in this. The theories explain behaviour in a task by describing the manipulation of information down to a level where a simple interpreter (such a digital computer) can turn the description into an effective process for performing the task. Not all versions of the theory are carried so far, of course. Newertheless, in general, the theory can deal with the full content of a task » (op. cit., p. 11) ;
- « The natural formalism of the theory is the program, which plays a role directly analogous to systems of differential equations in theories with continuous state spaces (for example, classical physics) » (ibidem).

Empirical synthesis

We saw earlier that the course-of-action analysis has the same ideal of "a theory (which) performs the tasks it explains". But the requirement of computer simulation of the psychological process claimed by Newell & Simon has been abandoned, as well as the methodology and the model of analysis (cf. section 7). This double abandonment is the outcome of the " enaction paradigm " : in order to be admissible, the description of the course-of-action protocols must respect the agents' autonomy and cannot be based on the task as seen by the observer ; a computer simulation cannot express this autonomy. It is destined to serve practical interests which will be considered in the following section – but, as we will see immediately, not only - rather than scientific interests.

This double abandonment is costly from a scientific point of view. The great strength of [25] – which enabled its fruitfulness for the cognitive task analysis - lay in the fact that its analytic model (states of information and information processing operators) corresponded to its synthetic model. In fact, the abandonment of the computer models is not absolute, but relative. These computer models, if they have no explanation value for the reasons given, can indeed have a predictive value and therefore contribute as such to the precision, to the fruitfulness and to the validation/falsification of the empirical hypotheses, despitesevere limitingtheir domain of application through course-of-action analysis. The research concerning courses-of-action and their collective interlinking, though they have lead to the design of various computer systems, have produced only few of these kinds of computer models, since we have concentrated more on other questions (nevertheless refer to [22], which will be mentioned later). But the emphasis put, by other researchers (see for instance [28]), on computer modelling of co-operative activities, so considered, without any illusion of scientific explanation, in letting it play at the same time a predictive role – and thus a role in the validation/falsification of the hypotheses – and a role in the design of computer controlled situations – by showing the consequences for the activity of some set of design decisions -, can be considered as complementary. This computer modelling of co-operation is being developed following previous theoretical construction and empirical modelling which are partly comparable, partly complementary and partly alternative to those of course-of-action analysis.

Parallel to this double abandonment, the research on the courses-of-action and their collective interlinking have looked for a new way to develop synthetic empirical models, but have not, up until now, produced a generic synthetic model, i.e. a generic model to be defined practically in the various situations. But it is easy to imagine that the generic analytical empirical model of the course-of-experience constituted by the hexadic sign and the significant fundamental structures enhances the appeal, for the construction of such a generic synthetic empirical model, to the mathematics of "dynamic systems determined by their initial state", i.e. a return to the differential equations denigrated in [25] with a more powerful mathematical theory (see [34],[43],[45]). However, it leads to consider the synthetic mathematical models, susceptible of being built in such a way, more as " humility injectors " (as expressed in [3]), than as models allowing a full mastery of the phenomena. Though through various partnerships since 1993, this way of modelling has been explored, no reductions relevant for empirical study and design have been established yet, nor collaborations and the means of research that could enable to overcome the simple metaphorical reference, that today is more and more widespread regarding these types of models.

The amphibology of cognitive task design and the object of course-of-action centred design

The cognitive task analysis performed in [25] leads up to the design of Artificial Intelligence systems able to replace human intelligence in problem solving. The course-of-action centred design, like most of the approaches of cognitive task design aim at something more complex : the design of " **joint cognitive systems** " combining human operators and computer systems replacing the operators for certain tasks. Hence this is what we could call the amphibology of cognitive task design.

We mentioned above that the course of action analysis has the same ideal as [25] of a "theory (which) performs the tasks it explains". With time, it thus opens up to systems susceptible of replacing the human operator for specific tasks or part of such. But the emphasis is put, not on the replacement of the human operator for specific tasks, which today require less and less cognitive task analysis (see the design principles of the celebrated chess program " Deep Blue "), but on the design of situations for this human operator. Extending the distinction made by Dave Woods between support and cognitive prosthesis (see [66]), it considers the **support situations** as its objects of design, i.e. situations which, with given operators' states and cultures, gives them the possibility of an activity which, at the same time, produces pleasurable involvement, satisfactory workload and security, adapted performance and learning.

The paradox of the course-of-action centred design of computerised and automated situations

As the aim is not to replace totally or partially the human operator by computer and automatic systems, but to design support situations, it can be considered that the course-of-action centred design should not take any computer model into consideration, except, as seen in the previous section, with regards to their limited predictive and heuristic virtues. As a matter of fact, this is not the case. The course-of-action centred design is indeed confronted with a paradox called the **paradox of the course-of-action centred design of computerised and automated situations.** On the one hand, the designers of computerised and automated situations require design scenarios and models of the man-machine-environment system which are computerised, whether they construct them themselves or not. On the other hand, such computerised scenarios and models are unable to account for the autonomy of the agents in such a system, present or future, as stated above. The solution of this paradox is that the underlying regularities of the courses-of-action drawn from the analysis of the courses-of-experience and the relation of these with the constraints and extrinsic effects together with the rest of the observable activity, can be translated more or less roughly into computer models the validity of which is limited to determined phases of the courses-of-action. This translation is, to use the classical formula, a betrayal, but one that can be useful to design if it is used with care and with full knowledge of the facts. While we are on the subject, we recall that in [58], Francisco Varela, one of the main initiators of the research on the autonomy of living systems, while convinced that the classical cognitive psychology today represents an obstacle to the development of the cognitive sciences, gave it a role in applications.

These computer models, in addition to their predictive value underlined in the previous section, play an important role in the design of support computer systems. So far, the researchon the courses-of-action and their collective interlinking, though they have lead to the design of a great number of computer systems, have produced less computer models for the design than scenarios for the design. As an example, in the study of [22], based on a semiological analysis of the courses-of-action of air traffic controllers, an analytical computer model of the air traffic control course-of-action and a computer model for the design of computer support systems for air traffic control, in using the formalism SA/RT (System Analysis / Real Time), have been developed successively. These two computer models have been limited to non-incidental situations of control in the airport zone (departure and arrival area). Their inspiration is based on a simplified version of the semiological notions. For instance, the state of preparation (**E, A, S**) has been reduced to a set of “ situation catalysers ” considered as pre-defined and not developing progressively in the course of action. The computer model for design takes into consideration more variable situations than those on which the analytical computer model is based, as well as the innovations foreseen in the design project. The same process leading from the semio-logical analysis to the construction of a computer model for design is applied in the ongoing study concerning the design of a multi-access system of control of domestic energy but using an adaptation of UML computer language [14].

9. COMPLEXITY & EMPIRICAL ITERATION ALONG THE DESIGN PROCESS

The paradox of the analysis for the course-of-action centred design

The set of methods of data collection and analysis, the development process of the hypotheses and the analytical models of the courses-of-action are not sufficient to define the rules of design related to a given design project. A solution to a second paradox is to be found, the **paradox of the analysis for the course-of-action centred design**, which concerns both the observatory and the analysis. This paradox is as follows. In order to elaborate design proposals for a future work situation based on the knowledge of the extrinsic constraints of the course-of-action, there should be no doubt about the course-of-action in this future situation. Within a design process, the course-of-action in this future situation will only be fully known when this future situation is completely designed and implemented. But then, the scope of the ergonomic contribution will be greatly reduced as the design will be totally completed. It will only be applicable for the next design process. This paradox is due to the complexity, the variety and the continuous transformation of the course-of-action and of its constraints : variety of the population of the users ; great dispersion and complex organisation of the relevant human characteristics ; variety and complex organisation of the relevant characteristics of the situation ; variety and complexity of the operators' experience. This is the reason why, if we state this paradox here in connection with the **design process**, we could also have stated it in connection with the **empirical knowledge process** in section 7.

The solution of this paradox, is the **iteration of the study of the course-of-action** in situations approaching more and more the future situation in as much as they have been selected or constructed progressively during the design process. Based on each of these situations, the results aimed at in the study of course of action do not constitute the knowledge of the course-of-action considered. These are only a means to target the future situation, to supply the recommendations concerning this future situation at a given time and in the form appropriate to the designers. The different kinds of analytical models of the courses-of-action have a predictive capacity. This predictive capacity is to be put at the disposal of the design of the future situation. Talking about the course-of-action centred design, we stress that the future course-of-action can only be anticipated through the knowledge of the past courses-of-action – especially that using modelling -, in the given present natural situation and other selected or constructed situations based thereon. The closer these situations are to the future situation, the more the design proposals based on these studies of courses-of-action gain in validity and in precision. The more their impact on the design gets marginal. This enhances the importance of the first stages compared with the following ones. At each stage of the design process, the design proposals made at the previous stage find themselves more or less validated or invalidated correspondingly. It is not necessary to wait for the final product. At each stage of the design process, the contributions to the design are based on the analysis of the data obtained at this particular stage, but also on the analysis of the data obtained at previous stages. This iteration can introduce itself naturally into the design process. These design processes are time-consuming. The designers of complex technical and organisational systems are themselves accustomed to iteration, as the behaviour of such systems retain a level of unpredictability as long as they are not effectively functioning. The main problems to solve are, on the one hand, the construction of the analysed situations, and on the other hand, the supplying of these situations by the designers at each stage.

The construction of the situations analysed at each stage

Let us begin with the examination of the construction of the analysed situations. They are first of all natural situations, amongst which it is necessary to distinguish **referential situations** and **springboard situations**. The referential situations enable the analysis of the course-of-action of given operators, having a given culture, in situations considered by the design project. The latter can be non-computerised or contain an unsatisfactory computer support. They also allow the analysis of the course of action of assistance brought to an operator by other more competent operators in these situations. The springboard situations enable the analysis of the courses-of-action in other situations containing a globally or partially more satisfactory computer support than the one present in the considered situation.

These natural situations are constructed, but not in the same sense as the ecological experimentation situations that we will consider next : they are only chosen. It is a choice to consider a particular given situation, either referential or springboard. It is a choice whether to analyse a given course-of-action of a given agent in this situation. These choices are based, on the one hand, on the knowledge obtained prior to the design project and process, and on the other hand, on the results of the familiarisation stage. These natural situations essentially enable the definition of the **functions of the technical system** and of **the essential characteristics of the environment, of the population, of the training and of the organisation.**

A further step forward in the construction of the analysed situations is the **ecological experiments in a natural situation**, either referential or springboard. These ecological experiments in a natural situation are concentrated on certain aspects which are particularly important for design. They enable to refine the results of the analysis in a natural situation and to improve their validation.

With the exception of the refinement and the validation, the ecological experiments in a natural situation play the same role for the design as the natural situations. This is not the case for the **ecological simulations and experiments on mock-ups or prototypes**, representing partially or completely the future situation, taking place outside the natural situations. Due to the advanced stage of the design, it is then no longer possible to question certain of its aspects. These ecological experiments and simulations on mockups or prototypes enable to define the specifications of the functions of the computer system and the essential characteristics of the environment, the population, the training and the organisation, identified earlier.

The same is not applicable to the situations based on **prototypes in pilot sites**. When such a prototype is put into a pilot site, the study of the course-of-action, whether in a natural situation or in an ecological experiment in a natural situation, does essentially enable to correct certain superficial aspects of the prototypes. But, it can also enable the refinement of the recommendations concerning implantation, workspace design, organisation, documentation and training of the future operators, identified earlier.

The study of the course-of-action during the **implantation phase** of a new device in the natural situations enables the validation or correction of the recommendations concerning the organisation, the documentation and the training, identified earlier.

Finally, the study of the course-of-action during **the life span of the new situation established** enables to take the changes occurred in the situation into consideration, to formulate new recommendations with regards to the organisation, documentation and training, to suggest superficial or local adaptations of the computer systems and to prepare the design of new versions of these systems.

All these situations should include natural agents. They can be ranked according to two criteria : the **distance to the natural situation** (past or future) and the **distance to the future situation.**

The supply of the situations analysed at each stage

Of course, the complete development of such an iteration implies that it should be possible to establish mockups and prototypes introducing a realistic interaction with the future operators. If this is not the case, the stages “ mock-up ”, “ prototype ”, and “ prototype in pilot site ”, should be replaced by a desk study or reduced scale model involving the course-of-action centred designers (based on the analyses of the courses-of-action) and various operators (based on their experience of the referential or springboard natural situations).

Though it is possible for a number of systems, in particular for all the office automation systems, to design mockups and prototypes allowing such a realistic interaction with the future operators, it is, at present, not a matter of course for most of the designers. The present trend is still to design mockups and prototypes that can be tested only from a technical point of view, i.e. which are not sufficiently developed to give a realistic interaction with the future operators. Such mockups and prototypes can at the very most lead to subjective reactions, proposals and remarks from the future operators. Only if the designers are convinced of the interest of the iteration of course-of-action analysis can the required complementary effort be integrated into the design process concerning mock-ups and prototypes sufficient for the ergonomic experiments. This has been the case in numerous course-of-action studies in connection with the design process of office automation systems [52].

With regards to the design of systems for nuclear process control, air traffic control and aircraft piloting systems, it is possible to rank, in the same way, studies in natural situations, studies on full scope simulators and studies on “ part task simulators ” (see {48] for a synthesis and [19] and [55] for course-of-action studies on full scope simulators).

Of course all these situations are not to be constructed in all the design processes. We have presented here what is possible. To decide what should really be constructed, it is necessary to consider the design process in more detail.

10. THE PRACTICE OF COURSE-OF-ACTION ANALYSIS IN COURSE-OF-ACTION CENTRED DESIGN

The models and scenarios for design

The course-of-action analytical models are developed in the aim of a contribution to design, but their construction is strictly determined by considerations about their empirical evidence and, more generally, about their coherence with the existing scientific knowledge concerning the different aspects of human activity. Inversely, the **scenarios and models for design,** concern future situations and integrate the design constraints. A **model for design** is a representation of the courses-of-action in the future situation likely to guide the design of this future situation. A **scenario for design** is the expression used rather for a partial model for design. We borrow this expression from John Caroll’s « scenario based design representations ». Such a scenario generally takes place within a group of several scenarios. With a model for design, the accent is being put on the unity of the design, whereas with a group of design scenarios, the accent is put on its multiplicity.

The rapid data collecting and analysis and the design

Based on the fact that the designers are currently submitted to heavy time constraints and therefore have a tendency to submit the cognitive task analysis to even heavier time constraints, the elaboration of fast but still effective methods (“ quick and not too dirty ”, to slightly reinterpret an accepted formula, or rather “ exactly useful ”, to use a formula proposed by [21]), for data collecting and analysis of the courses-of-action, for diagnosis-prognosis and design recommendation formulation, has a crucial role in the development on the course of action centred design.

First of all, the rapidity of the methods is to be considered against the global design process. Time should not be gained at one stage only to be lost at another. Next, this is to be considered, not definitely, but in connection with the characteristics of the situations to be changed, of the design projects and processes. Just as the course-of-action, this rapidity is situated. As a result, in order to be quick, it is necessary first to have been thorough, and hence slow. According to the results of the past studies and research concerning course-of-action centred design, faster and faster methods can be applied at all stages of the iteration of the contribution to design, starting with the preliminary study, where the design orientations and their specification mode are defined, up until the studies during the life span of the new installed situation.

It should also be stressed that gains in rapidity which can maintain efficiency, essentially rely on a judicious choice of the data and analyses and not on the confidence in data collected outside the work situation. The latter are easier to obtain, but their reliability is illusory unless they are in phase with the data in situation and if they only play a quantitative role. Because of the situated character of the course-of-action, of the complexity of its intrinsic constraints in the agent's state, situation and culture, the value of data outside the work situation can only be appreciated in connection with data in work situation.

Let us finally notice that the participation of the operators in the design process, in collaboration with the course-of-action analysts and the designers, can make the different stages more rapid. It can reduce the time of familiarisation for the analyst, allow a faster choice of the situations to be analysed, allow a faster generalisation of the results of a course of action analysis, enable to judge faster the possible harmful consequences of a given recommendation for the design produced following a limited study of the course of action. The results obtained in the course of action study can contribute to the selection and to the precision of the participation methods and thereby increase their efficiency and validity. Let us add that, in certain cases, even if not connected with a course of action analysis, the implementation of participation methods, selected and specified thanks to other past course-of-action studies, can supply the design with efficient and valid inputs. The problem is then that, on the one hand, it is difficult to foresee this efficiency and this validity, on the other hand, it is impossible to know if a course-of-action analysis could not have given more efficient and more valid inputs.

This is, for instance, according to such principles that have been developed, with regards to the studies of drivers' activity aiming at Advanced Driving Assistance devices design, what we called a comprehensive activity analysis [63].

The inputs to the design project development

Whatever the design project may be, the contribution to it will at least go through a course of action analysis, due to the complexity and the variety in the characteristics of the agents' state, situation and culture. But this does not mean, that no recommendation can be made to the project and to the design process prior to this analysis. Otherwise, what would the use be for the elaboration and the validation of hypotheses and courses-of-action analysis models, the construction of criteria and design indicators in terms of support, the construction of directing concepts, operational concepts, rules, scenarios and models for design, i.e. everything that has been developed in the prior research ?

In certain cases, it is possible to carry out a course-of-action analysis even before a design project has been precisely formulated and before its realisation process has started, i.e. at the very development stage of the design project. When this is not possible, the prior course-of-action centred design research and studies can nevertheless supply this design project and process with inputs. More precisely, the results of prior research and studies enable the formulation of preliminary recommendations that we qualify as **design orientations.** As these results of prior research and studies also concern design itself, they also enable toestablishthe **specification mode of these orientations in the course of the design process.** They are, for instance, the design modalities of an experimental mockup, the construction of a group to supervise the design including the relevant categories of operators. Generally, this is sufficient to establish the framework of the project and the expected design process and to make a preliminary study – which can be reduced to a simple visit –in the situations covered by the project.

From hypotheses and models of transformation to diagnosis-prognosis and design

After the inputs to the design project and process, have been provided, the iteration of the courses-of-action and their collective interlinking studies all along the design process can begin. It is possible to generalise what we have said with regards to the specifications of the design orientations prior to the design project and process. The specifications of the design orientations produced during this iteration must be given to the designers when they require them. Specifications supplied before or after each adequate design stage would impede instead of helping the designers.

At each stage of this iteration, it is necessary to construct and validate the **models or hypotheses concerning course-of-action transformations,** to base thereon a diagnosis-prognosis concerning the future situation, and to formulate an **effective contribution to the design adapted to the considered level of design.** Each one of these stages requires decision. The course-of-action centred design is never a simple application of knowledge resulting from a course of action study or other studies and research.

The move **from the models or hypotheses about course-of-action transformations to the diagnosis-prognosis concerning the future situation** constitutes a jump from the knowledge of the existing, to the practice of design. Included are, not only the course-of-action study (the study completed at this stage, those completed in prior stages, the prior studies of other situations and design projects), but also the results of other studies and research in psychology, physiology, etc., which have been selected in literature, and a good deal of expertise. The more detailed this diagnosis-prognosis will be for different **characteristic situations**, the more useful it will be for design. These characteristic situations (introduced by [18]) are typical organisations and contents of features of the extrinsic constraints of the course-of-action which could occur in the future situation. They are constructed based on the comparison of the results of the course-of-action study and the progress of the design project at the stage considered.

The move **from the diagnosis-prognosis to the effective contribution for design** constitutes the second knowledge-jump from the existing to design practice. It is never a matter of copying the previously analysed situations. That is exactly where the related directing and operational concepts and general and ad-hoc rules for design, whether organised or not in systems of rules, are specified.

While defining these rules for the different characteristic situations established, it is possible to elaborate **scenarios** and **models for design**. The notion of **characteristic situation** enables the applicaiton of a new specification to the latter.

Let us add that at each stage of input to design, a certain participation of the operators and the designers is required. With regards to the content, the methods, the cost and the inputs of this participation, the past experience does not enable us to extrapolate general rules. We can only say that they depend on the characteristics of the situations to be transformed, of the given design project and process.

CONCLUSION

Let us consider now the design process as a whole. This design process can be considered as the interlinking of the individual-social courses-of-action of numerous agents. These different courses-of-action take into consideration the pre-defined procedures but do not always comply therewith. These agents are, overall the operators, the technical designers, the course-of-action analysts and the course-of-action centred designers. The extrinsic constraints are the actual agents' states, the (dynamic) situation of the design and the culture, partly distributed, partly shared, of the different agents. Therefore, the problem of the course-of-action centred design appears as contributing to a collective interlinking of the courses of action of the different design agents having the following effects : a pleasurable and stimulating involvement in the design situation for these different actors ; an efficiency of the design process from the viewpoint of the support to future production and maintenance operators ; a development of the knowledge of the different agents which will enable them to tackle in an even better way the future design processes.

From this stems a global ideal. At first, this ideal is that all the design agents take as one of the objects of design the support situation and only relate to the technical division of work as a means. Next, it is the situation of the different design agents that enables them to participate in an optimal way in the design. For example, this is the case : if (1) the course-of-action analysts and course-of-action centred designers have access to data in natural situations and to the necessary ecological means of experimentation and if the designers receive the recommendations at the right moment ; if (2) the operators have access to the design information, can participate in the data collection and analysis and dispose of time for this. It is also the case if (3) there exists a sufficient mutual training of the different actors with regards to their different languages, objects, methods and common-sense or scientific theories. Finally, it is the case if (4) the limits of competence of each agent are sufficiently determined as well as the corresponding co-operation and co-ordination means (meetings, means of communication). To these ideal characteristics of the design process, it is necessary to add prerequisite conditions of which the principal is that the relevant scientific research in course-of-action analysis is being conducted and its communication and its part in the renewal of the training of the experts are assured.

The design processes and their conditions rarely correspond to this global ideal. The individual-social course-of-action of the cognitive task designer working through the course-of-action centred design approach should aim to approach this ideal. Independently of the degree of realisation of this global ideal, it is therefore, at one and the same time, directed towards the overall design situation, directed towards its major object (articulation between its design object and its analysis object) and directed towards the other design agents. Its horizons are manifold : to contribute to the ongoing design process ; to develop locally or globally the course of action centred design ; to improve his own skills as a course-of-action analyst and course-of-action centred designer ; to develop the communication with the other design agents. Obviously, the full development of this individual-social action requires the active participation of the course-of-action analyst in the design, and not just the supplying of recommendations now and then. It goes without saying, that success depends on the course-of-action analyst, but also of the other design agents and a great number of economical, social, cultural and political factors. For the course-of-action analyst, as for any of us, the most difficult finally, is to distinguish, as recommended a long time ago by the slave-philosopher Epictetus, between what is up to him and what is not.

REFERENCES

[1] BEAUFORT P. (1997) Le projet de l'action créatrice, Ph. D., Faculté des lettres, Université Laval, Québec.

[2] BOUZIT A. N. (1995) Analyse et conception de situations d'interaction à distance : cas de l'accueil téléphonique de la clientèle assisté par ordinateur, Thèse de doctorat en ergonomie, Université Paris 13, France.

{T15} THEUREAU J. (2002) First version fully developed of a chapter « course of action centred design », proposed for E. Hollnagel ed., *Handbook of cognitive task design*, Lawrence Erlbaum Ass.

[3] COWAN G.A., PINES D. & MELTZER D., *Complexity : metaphors, models & reality*, Santa Fe Institute studies in the sciences of complexity, Addison Wesley, Reading, 1995.
[4] Von CRANACH M., FOPPA K., LEPENIES W., PLOOG D. eds (1979) *Human ethology, claims and limits of a new discipline*, Cambridge University Press - Maison des sciences de l'homme, New York-Paris.
[5] Von CRANACH M., HARRE R. eds. (1982a) *The analysis of action. Recent theoretical and empirical advances*, Cambridge Univ. Press- Editions de la Maison des Sciences de l'Homme, Cambridge-Paris.
[6] Von CRANACH M., KALBERMATTEN U., INDERMUHLE K., GUGLER B. (1982b) *Goal directed action*, Academic Press, London.
[7] Von CRANACH M., KALBERMATTEN U. (1982) Ordinary goal directed action in social interaction, in W. Hacker, W. Volpert, M. von Cranach eds., *Cognitive and emotional aspects of action*, North Holland Pub co, Amsterdam.
[8] DUFRESNE R. (2001) *Le contrôle des environnements dynamiques : étude ergonomique dans une perspective d'automatisation d'un système de contrôle de la circulation ferroviaire*, Thèse de doctorat d'ergonomie, École Pratique des Hautes Études, Paris, France.
[9] EDELMAN G.M. (1992) *Biologie de la conscience*, Editions Odile Jacob, Paris.
[10] ERICCSON K.A., SIMON H. (1980) Verbal reports as data, *Psychological Review*, 87, n°3.
[11] ERICCSON K.A., SIMON H. (1984) *Protocol Analysis. Verbal reports as data*, MIT Press, Cambridge.
[12] FILIPPI G. (1994) *La construction collective de la régulation du trafic du RER: étude ergonomique dans une perspective de conception de situations d'aide à la coopération*, thèse de doctorat d'ergonomie, Université Paris 13.
[13] HARADJI Y. (1993) *De l'analyse de l'aide humaine à la conception d'une aide informatique à l'utilisation d'un logiciel*, Thèse de doctorat en ergonomie, Conservatoire National des Arts & Métiers, Paris, France.
[14] HAUÉ J-B. (to be published) *Conception d'interfaces multi-accès centrée sur l'activité des utilisateurs*, Thèse de doctorat en contrôle des systèmes, Compiègne, France.
[15] HEATH C. & LUFF P. (1991) Collaboration and activity and technical design; task coordination in London Underground Control Rooms, *Proceedings of the Second European Conference on Computer Supported Cooperative Work*, September 24-27, Amsterdam.
[16] HUTCHINS E., *Cognition in the wild*, MIT Press, 1994.
[17] GAILLARD I. (1992) *Analyse de l'activité et des savoir faire d'opérateurs experts – le cas des contrôleurs du trafic aérien lors d'un changement de la position de contrôle*, Thèse de doctorat d'ergonomie, Université Paris 13, France.
[18] JEFFROY F. (1987) *Maîtrise de l'exploitation d'un système micro-informatique par des utilisateurs non-informaticiens : analyse ergonomique et processus cognitif*, Thèse de doctorat en ergonomie, Conservatoire National des Arts & Métiers, Paris, France.
[19] JEFFROY F., THEUREAU J. & VERMERSCH P. (1998) *Quel guidage des opérateurs en situation incidentelle/accidentelle ? Analyse ergonomique de l'activité avec procédures*, IPSN/DES/SEFH , Clamart.
[19] JEFFROY F., THEUREAU J. & VERMERSCH P. (2000) Controling a nuclear reactor in accidental situations with symptom-based computerized procedures : a semiological & phenomenological analysis, *CSEPC 2000*, Taejon, Corée, 22-25 Novembre.
[20] JOURDAN M. (1989) Développement technique dans l'exploitation agricole et compétence de l'agriculteur, Thèse de doctorat en ergonomie, Conservatoire National des Arts & Métiers, Paris, France.
[21] LAMONDE F. (1992) *La détermination progressive de l'activité des ingénieurs de locomotive : contribution à l'analyse de la fiabilité d'un système ferroviaire*, Thèse de doctorat en ergonomie, Université Paris 13, France
[22] LAVAL V. (1993) *Modélisation de l'activité d'opérateurs d'un système complexe dans une perspective de conception de supports informatisés*, thèse de doctorat d'ergonomie, Université Paris 13, France.
[23] LEBLANC S., SAURY, J., THEUREAU J., DURAND M. (accepted) Apprentissage dans un environnement multimédia, *Computers & Education*.
[24] LESTIEN A (1984) *Une approche ergonomique de l'automatisation dans les industries à production séquentielle*, Thèse de doctorat d'ergonomie C.N.A.M., Paris.
[25] NEWELL A. & SIMON H. (1972) *Human problem solving*, Prentice-Hall, Englewood Clifs.
[26] NORMAN D.A. & DRAPER W.D. (1986) User centred design, Lawrence Erlbaum ASS., Hillsdale.
[27] OMBREDANE A. & FAVERGE J.M. (1955) *L'analyse du travail*, PUF, Paris.
[28] PAVARD B. ed. (1994) *Systèmes coopératifs: de la modélisation à la conception*, Octares, Toulouse, France.
[29] PETITOT J., VARELA F.J., PACHOUD B, ROY J.M. (1999) *Naturalizing Phenomenology*, Stanford University Press.
[30] PIATELLI-PALMARINI M. (1979) *Théories du langage, Théories de l'apprentissage : le débat entre Jean Piaget et Noam Chomsky*, Seuil, Paris.
[31] PINSKY L. (1992) *Concevoir pour l'action et la communication : essais d'ergonomie cognitive*, Peter Lang, Berne.
[32] PINSKY L., THEUREAU J. (1982) *Activité cognitive et action dans le travail. Tome 1 : Les mots, l'ordinateur, l'opératrice*, Collection de Physiologie du Travail et d'Ergonomie n° 73, CNAM, Paris.
[33] PINSKY L., THEUREAU J. (1987) Description of visual "action" in natural situations, in O' Regan, J. K., Levy-Schoen A. eds., *Eye mouvements: From physiology to cognition*, Selected/edited proceedings of the 3rd European conference on eye mouvements, Dourdan (France), Sept, Elsevier, Amsterdam.
[34] PORT R.F., VAN GELDER T. (1995) *Mind as motion: explorations in the dynamics of cognition*, MIT Press.
[35] RIA L. (2001) *Les préoccupations des enseignants débutants en éducation physique et sportive : étude de l'expérience professionnelle et conception d'aides à la formation*, Thèse en Sciences et Techniques de l'Activité Physique et Sportive, Université de Montpellier, France.
[36] ROBINEAU S. (2000) *La construction de la magie spectaculée : analyse de la pratique et cognition située*, Mémoire de Sciences de l'Homme & Technologie, Université de Compiègne, France.
[37] ROSENFIELD I. (1988) *The invention of memory, a new view of the brain*, Basic Books, New York.

{T15} THEUREAU J. (2002) First version fully developed of a chapter « course of action centred design », proposed for E. Hollnagel ed., *Handbook of cognitive task design*, Lawrence Erlbaum Ass.

[38] SAURY J. (1998) *L'action des entraîneurs dans les situations de compétition en voile olympique – contribution à une anthropologie cognitive du travail des entraîneurs sportifs, finalisée par la conception d'aides à l'entraînement*, Thèse en Sciences et Techniques de l'Activité Physique et Sportive, Université de Montpellier, France.
[39] SAURY J., DURAND M. & THEUREAU J. (1997) L'action d'un entraîneur expert en voile en situation de compétition : étude de cas. Contribution à une analyse ergonomique de l'entraînement, *Science et Motricité*, **31**, 21-35.
[40] SÈVE C. (2000) *Analyse sémiologique de l'activité de pongistes de haut niveau lors de matchs internationaux – contribution à une anthropologie cognitive de l'activité des sportifs finalisée par la conception d'aides à l'entraînement*, Thèse en Sciences et Techniques de l'Activité Physique et Sportive, Université de Montpellier, France.
[41] SÈVE C., DURAND M., SAURY, J., THEUREAU J. (accepted) Activity organization and knowledge construction during cognitive interaction in table tennis, *Cognitive Systems Research Journal*, special issue on situated and embodied cognition.
[42] SIMON H.A. (1977) *Models of discovery*, D. Reidel, Dordrecht.
[43] SMITH L. B., THELEN E. eds. (1993) *A dynamic systems approach to development: applications*, MIT Press.
[44] SUCHMAN L. (1987) *Plans and situated action*, Cambridge University Press, Cambridge.
[45] THELEN E., SMITH L. B. (1995) *A dynamic systems approach to the development of cognition and action*, MIT Press.
[46] THEUREAU J. (1992) *Le cours d'action: analyse sémio-logique: essai d'une anthropologie cognitive située*, Peter Lang, Berne.
[47] THEUREAU J. (1997) L'émergence d'un complexe d'échanges à travers les trajets des voyageurs : essai méthodologique , in Bayart D., Borzeix A., Lacoste M., Theureau J., *Les traversées de la gare : la méthode des trajets pour analyser l'information-voyageurs*, n° 118, RATP, Département du Développement, Mission Prospective et Recherches Sociétales, Paris, pp. 145-190.
[48] THEUREAU J. (2000a) Nuclear reactor control room simulators : human factors research & development, *Cognition, Technology & Work* , 2 : 97-105.
[49] THEUREAU J. (2000b) Anthropologie cognitive & analyse des compétences, in J.M. Barbier, Y. Clot, F. Dubet, O. Galatanu, M. Legrand, J. Leplat, M. Maillebouis, J.L. Petit, L. Quéré, J. Theureau, L. Thévenot, P. Vermersch, *L'analyse de la singularité de l'action*, collection Education & Formation, PUF, Paris, 171-211.
[50] THEUREAU J. (2000c) L'analyse sémio-logique des cours d'action et de leur articulation collective en situation de travail, in A. Weill-Fassina & T. H. Benchekroun, *Le travail collectif – Perspectives actuelles en ergonomie*, Octares, Toulouse, 97-118.
[51] THEUREAU J. (to appear, 2001) Dynamic, living, social and cultural complex systems : principles of design-oriented analysis, in Benchekroun H. & Salembier P. eds., *Cooperation & complexity*, Hermes, Paris.
[52] THEUREAU J., JEFFROY F. & COLL. (1994) *Ergonomie des situations informatisées : la conception centrée sur le cours d'action des utilisateu*rs, Octares, Toulouse.
[53] THEUREAU J., FILIPPI G. (1994) Cours d'action et conception d'un système d'aide à la coordination: le cas de la régulation du trafic du RER, *Sociologie du Travail*, **4**, 547-562.
[54] THEUREAU J., FILIPPI G. (2000) Analysing cooperative work in an urban traffic control room for the design of a coordination support system, chapter 4, in, P. Luff, J. Hindmarsh & C. Heath eds., *Workplace studies*, Cambridge Univ. Press, 68-91.
[55] THEUREAU J., FILIPPI G., SALIOU G. & VERMERSCH P. (2001) Development of a methodology for analysing the dynamic collective organisation of the reactor operator's and supervisor's courses of experience while controling a nuclear reactor in accidental situations in full scope simulated control rooms, *CSAPC'01*, 23-26 Septembre, Munich, Germany.
[56] VARELA F.J. (1980) *Principles of biological autonomy*, Elsevier North Holland, New York.
[57] VARELA F.J. (1989a) *Connaître : les sciences cognitives*, Seuil, Paris.
[58] VARELA F.J. (1989b) *Autonomie et connaissance*, Seuil, Paris.
[59] VARELA F., THOMSON E., ROSCH E. (1991) *The embodied mind: cognitive science and human experience*, MIT Press
[60] VEYNE P. (1971) *Comment on écrit l'histoire*, Seuil, Paris.
[61] VERMERSCH P. (1994) *L'entretien d'explicitation*, ESF, Paris.
[62] VILLAME T. (1992) *Modélisation des activités de recherche d'information dans les bases de données et conception d'une aide informatique*, Thèse de doctorat en ergonomie, Université Paris 13, France.
[63] VILLAME T. & THEUREAU J. (2001) Contribution of a 'comprehensive analysis' of human cognitive activity to the advanced driving assistance devices design, *CSAPC'01*, 23-26 Septembre, Munich, Germany.
[64] VION M. (1993) *Analyse de l'apprentissage médié sur le tas : le cas du travail de guichet à l'hôpital*, Thèse de doctorat en ergonomie, Université Paris 13, France.
[65] VION M. (1996) *Analyse ergonomique de l'activité de pêche au chalut pélagique à la passerelle d'un simulateur de formation maritime*, Laboratoire Sécurité et Conditions de Travail à la Pêche Maritime, Lorient.
[66] WOODS D.D. & ROTH E.M. (1990) Models and theories of human computer interaction, in M. Helander ed., *Handbook of Human Computer Interaction*, North Holland, 3-43.