Micro-Cognitive-Processes at the Interface Research-Education-Problem Solving

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ABSTRACT

A first part of this paper gives a rough picture of some difficulties encountered in research, in education, and in problem solving, for integrating them to one another. One can notice a much too global characterization of cognitive processes and a lack in the characterization of semiotic aspects. A second part analyses some theoretical limits to this integration. They are mainly due to the current conception of memories unable to take into consideration the micro-cognitive-processes at work under the reorganizations of knowledge when actualized within the situation. A third part presents a way toward the integration research-education-problem solving, relying on a cognitive approach of Culioli's enunciative theory of language, and presents some of the author's data. Micro-cognitive-processes are depicted in terms of the construction of aggregates (declarative versus procedural ones, standing at different levels of internalization and externalization), and of different processes of detachment from the situation. Then several kinds of interactions allow an on-line identification of the constraints of the task. The characterization of these constraints seems basic for each of the considered areas, research, education, and problem solving.

Keywords: micro-cognitive-processes, functional meaning, reorganization of knowledge, cognitive linguistics, cognitive units, declarative versus procedural units.

1. INTRODUCTION

Our suggestions for integrating research, education, and problem solving are both theoretical and methodological. Our intent is to provide some hints about the micro-cognitive-processes underlying information processing and decision making. For that, we will depict a rough picture of some difficulties and limits encountered in each of these areas. Then, we emphasize some theoretical dead ends, underlying those limits. Finally we review some of our data showing how we try to open a way possibly integrating the three areas research, education, and problem solving.

2. PROBLEMS FOR INTEGRATION

A multiplicity of ingenious and various simulations have been proposed in the problem solving area, especially at the interface between education and informatics. But the help they provide to subjects' learning remains very limited, and can hardly be generalized to other situational contexts. Indeed, most of them suffer from an inadequacy in the theoretical and methodological analysis of the cognitive aspects which are simulated. The challenge is to understand how learning proceeds. An important step was made in CLARION model [16] which constructs an interaction between implicit and explicit knowledge, close to Piaget's theory [11]. The interesting point stands in a process of re-inscription of implicit knowledge in explicit form. That allows the construction of new rules and of a functional planning. Nevertheless, the usual identification remains between declarative and explicit levels and between implicit and procedural levels, and the distinction between internal and external knowledge remains confused.

Another difficulty concerns the identification of semiotic aspects. Most researches rely on a conceptual approach which directly refers to events or objects or knowledge stored in memory. The notion of functional meanings in Piagetian theory [11], [12], allows to describe the way in which children attribute meanings to the situation. For example, Blanchet's experiment with a train[1] shows some early difficulties for young children, linked to external meanings attributed to the situation [11]: to partition the train into procedural units; to attribute the meaning of a parking track to the goal track; to understand that for turning the train right, the turning slab has to turn left. Following Cellerier [6], this example shows that the procedural units have to

[1] At a triple intersection of tracks forming a T, a train has to pass over a round turning slab on which only the engine and a truck can take place. The children have to make the train turn along one side of the two opposite tracks of the T.

be coordinated with the representative declarative units and re-inscribed at a more abstract level. Furthermore, the structured procedural units may become representative units. This interesting approach is generally ignored by most researchers. And the understanding of functional meanings attributed by children to objects and actions remains poor most of the time in many researches. In fact, a well-known limitation of the Piagetian approach is that the formal cues of functional meanings are generally not clearly defined.

Moreover, the usual distinction between verbal modality and imagery remains too rough. Opposite systems may appear within an analogical level, as shown by Caron-Pargue's children's drawings of two cubes with two labels stuck respectively on the middle of two adjacent versus opposite faces [5]. Fig. 1 shows that the correct 3-D Necker graphical representation of a cube becomes a 2-D perceptive representation. The faces of the cube are partitioned by graphical lines into several parts on which the stickers are drawn. The functional meaning of this drawing is given by the difference between the graphical positions of the stickers beyond the analogical common graphical representation of the cube itself.

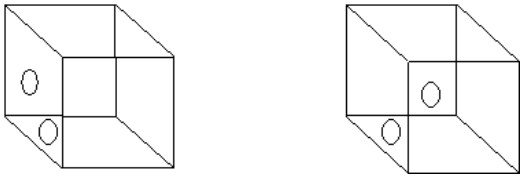

Fig. 1. Ten-year-old drawing of two cubes with labels stuck respectively on adjacent and opposite faces.

Finally, most cognitive researches rely on the subjects' performances without considering the different cognitive processes which can underlie the same performance. Furthermore, these performances are mainly evaluated in the case of well-defined strategies, for example when the strategy is optimal with the Tower of Hanoi puzzle. The strategy of novices is rarely considered in spite of Newell and Simon's early approach [14]. The usual characterization of cognitive processes remains much too global, in terms of goal-stacks and recursive strategies, or of priming, strengthening, inhibitions, and interferences. However, we must mention the interesting distinction made by some authors (e.g. Clancey [7], VanLehn [17]) between two kinds of generalization, one, linked to abstraction, which requires attention and time, the other, automatic, leading to a improvment in performance. Likewise, the notion of external memories must be mentioned, even if their construction and the processes of their interactions with internal representations must be specified (cf. Clancey [8], Zhang [18]).

3. THEORETICAL LIMITS

The above difficulties and limits are linked to the current cognitive conceptions of memory and of language, for which the micro-cognitive-processes at work have still to be defined. The possibility of this definition depends on several theoretical points.

A first point is that the reorganizations occurring between knowledge stored in memory and knowledge contextualized in the current situation must be taken into account, and formalized. In fact, the retrieval of knowledge stored in memory is generally conceived as a process of activation by external cues of a subset of this memory composed of more or less associated elements. But no reorganization of the previous structure of knowledge is conceived within the retrieval. In fact, if reorganizations are considered, they are conceived through generation processes. And only the result of these reorganizations is considered as stored in memory. The micro-cognitive-processes at work throughout the process of generation remain unknown. The knowledge is generally considered as being automatically activated by external information. That is the case only when the context remains rigorously the same or when knowledge becomes completely decontextualized. But the different steps of decontextualization remain unconsidered in such theoretical approaches.

A second theoretical limit concerns the way in which semiotic aspects are considered. Most of current models of memory characterize cognitive meaning as conceptual. Indeed, it is necessary to start with something. But the inadequacy stands in the way in which flexibility is added to this conceptualization. It does not take into account the micro-cognitive-processes at work in the semiotic modifications of concepts. Some progress was made toward taking into account functional or contextual meanings with the notion of affordances. But here

again the inadequacy stands in the automatic activation of all the properties of the concept. In fact, affordances are generally conceived as giving access to abstraction, i.e. to all connections given by the concept, themselves considered as always operating in the current situation. However, as it is well known in education, these processes cannot be automatically at work [11], [15]. They must be constructed but the challenge is to know how this is done. The theoretical inadequacy concerns the way in which the micro-cognitive-processes allow to identify the constraints of the task. In other words, how can the contextual meaning be generalized? More generally, the interactions between internal and external memories cannot be viewed as simple exchanges of information, without any reorganization. It is the support of information, its medium, which plays a role in the transformation of information, and refined semiotic aspects have to be taken into account at this level.

Finally, similar limits due to semiotic aspects occur with language, notably for its psychological approaches, which rely generally on a litteral conception of meaning mistaken for reference. That entails misunderstandings in the use of verbal reports [2], [3]. Therefore such a view is unable to account for cognitive strategies, and a number of researchers do not want to consider verbal reports. Another consequence is a disconnection between studies bearing on the cognitive representations, and those bearing on communication. However, language plays an important role, notably in education where communicative and representational purposes should always be integrated together. In fact, language should be considered as a behavioral observable cue as worthwhile as every other else. The key point is not the information itself but the way in which information is given. For example, different lexical choices referring to the same event or object have to be differentiated in order to grasp the functional meaning attributed to this event or object. Our view relies on cognitive linguistics [9], [13], for which syntax is meaningful, and constitutes formal cues open to a cognitive interpretation.

4. TOWARD INTEGRATION

In this part, we will refer to our data in order to show how we began to solve these difficulties. We referred to the cognitive interpretation of two kinds of enunciative operations, the basic operation of location, and the processes of detachments from the situation. That led us to a functional distinction between declarative and procedural levels.

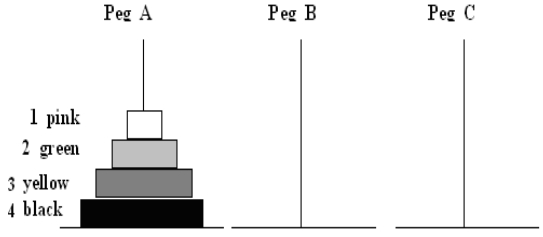

Fig. 2. Tower of Hanoi puzzle: configuration of the initial state. Goal: move all disks to peg C with the same configuration.

All our examples will refer to verbal reports obtained simultaneously to the solving of the 4-disks-Tower of Hanoi puzzle (cf. Fig. 1). The subjects have to move all disks to peg C, one disk at a time without placing a big disk on a smaller one.

To grasp micro-cognitive-processes

To grasp micro-cognitive processes is a complex challenge. In fact, it involves the articulation of many theoretical fields, on specific points which are not always completely constructed. For that, we think that the formal linguistic model of Antoine Culioli [9], [10], constitutes an interesting approach. Indeed, this model relies on an original articulation among philosophical, semiotic, and linguistic approaches. Language is viewed as basically intersubjective and is formalized by means of enunciative operations at different steps of reorganizations between notions (stored in memory) and the discursive contextualized situation. Our claim is that a cognitive interpretation of enunciative operations must lead to a grasp of some micro-cognitive-processes at work throughout the reorganizations of propositional contents stored in memory. Indeed, it is a fact that not every cognitive activity leads to a linguistic expression. But elementary micro-cognitive-processes could not be so numerous. So, when they begin to be identified, they can be considered as underlying as well linguistic levels as non-linguistic ones.

Aggregates toward chunks

The cognitive interpretation of the basic enunciative operation of location (in French: ‘repérage’) is close to the notion of ‘point of reference’ in Langacker’s

cognitive linguistics [13]. Then, in Culioli's terms, the location of the 'locatum' *b* located relatively to the 'locator' *a* in the oriented predicative relation *< a R b >* can be interpreted as *a* and *b* coming together, with an attentional focus bearing on *a*.

The interesting point, notably for education, stands in the possible identification of elementary cognitive units, which we called 'aggregates', when the operation of location is applied to two consecutive events or actions. For example, in the case of the solving of a puzzle like the Tower of Hanoi, the operation of location is marked by the repetition of lexical choices *the green disk* in *I put the green disk on peg C – I put the pink disk on the green disk* and the repetition of *peg C* in *I put the green disk on peg C – I put the pink disk on peg C*. That shows that the subject is thinking of one mental action instead of two. Then, it is possible to follow the progressive construction of larger cognitive units.

Aggregates constitute elementary cognitive units, which contribute to the construction of chunks [2], [3], [4]. In fact, a chunk may be considered as resulting from two reverse aggregates, bearing on the same elements but with a reverse attentional focus between them. Nevertheless our analyses showed that subjects used to construct aggregates most of the time but rarely true chunks.

Detachments from the situation

But the most interesting aspects concern the identification of two kinds of detachments from the situation, one marked by starting terms, the other by modal terms [3], [4].

Starting terms: One of the two arguments of an oriented predicative relation takes the status of starting term if it is extracted from the predicative relation and replaced by an anaphora. For example, *the green disk* takes the status of being a starting term first argument, marked by anaphora *it* in *the green disk I put it on peg C*. Likewise *the green disk* takes the status of a starting term second argument marked by anaphora *it* in *I take the green disk I put it on peg C*.

The status of starting term defines a first level of contextualization of the predicative relation which can be located either relative to the starting term or to the situation. Then in our data we interpreted the starting term as the marker of the distinction between an internal representational space and an external one [2]: the internal space is marked by the presence of a starting term; the external space is marked by the absence of a starting term. Then, different kinds of aggregates were defined [3], [4]: external aggregates, when there is no starting term; internal aggregates when there is an aggregate between two starting terms, due mainly to an anticipation (e.g. *the green disk I put it on peg C in order to move the pink disk – the pink disk I put it on peg C)*, or to a return to the previous action (e.g. *the green disk I put it on peg C – the green disk is on C I take the pink disk I put it on peg C*).

Another basic enunciative function of a starting term is to give access to abstraction and to reconstruct the notions within its previous place in the predicative relation. We proposed an articulation of this function with Piaget's processes of internalization and externalization ([2], [6], [15]). That led us to consider the cognitive function of the starting term as marking the reconstruction of the external aggregates at the internal level, that is internalization, and as the reconstruction of the internal aggregates at the external level, that is externalization. Then an intermediary aggregate, called 'categorized aggregate' was defined as marker of interaction between internal and external spaces. In the example *the green disk I put it on peg C – I put the pink disk on peg C*, the external aggregate marked by the repetition *on peg C* is categorized by the starting term *the green disk*, itself marked by anaphora *it*, and reconstructed at the internal level. Its reconstruction appears as detached from the current situation and can be re-used in another situation. This decontextualization may be completed when it will be articulated with another categorized aggregate giving rise to its externalization (see [3] and [4]). Then, the starting term appears as the marker of a process of decontextualization by means of an articulation between internalization and externalization, in contrast to the classical process of decontextualization by repetition of similar events or actions. Categorized aggregates are the necessary condition of an elementary step of generalization to another situation.

Modal terms: At the enunciative level, modal terms involve a detachment from the current situation, with the purpose of reorganizing the situation. In our data, we interpreted the presence of a modal term in terms of a differentiation between a strategic access to memory and an automatic one

[3], [4]. This differentiation concerns as well the planning (with modal verbs such as *can*, *want*, *have to*), the initialization of a sequence (with interjections such as *well*), the storage in memory (with interjections in the context of action *oh*, *oh yes*, *no*), and the retrieval (with modal evaluations such as *oh it is fine*, or *I believe that I am blocked*). These strategic activities mark uncertainty and difficulties because the subject does not understand well all the internal constraints of the situation. At the opposite, when there is no modal term, the subject remains within the situation, without major subjective difficulties, structuring the external space. Finally, the basic property of modal markers is to consider information at different levels of processing in order to reorganize the current situation.

Identification of constraints: The enunciative theory of Culioli considers various kinds of detachments which can be added to one another so as to finally turn back to the situation. It is the case with the strange loop (cf. fig. 2). In fig. 2, *p* is the situation, and *p'* anything else other than *p*; *pp'* is a detachment from both *p* and *p'*, and *p!* a detachment from *pp'*; the arrows mark the allowed paths from a level to another one. Each of these arrows is matched to a detachment process. We can see that we can be detached from the current situation *p*, and that, adding several kinds of detachments, following the arrows, we can return to *p*. The loop becomes strange when the path passes across *p!*.

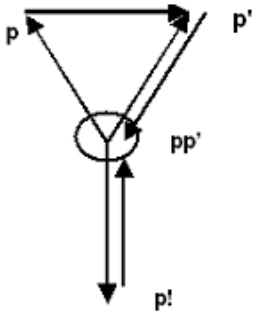

Fig. 3. Culioli's diagram

In our approach, we placed on Culioli's diagram every consecutive occurrence of one or other of our two kinds of detachments, marked by modal terms or by starting terms, during a complete solving of the Tower of Hanoi puzzle. The successive steps of this path were cognitively interpreted according to Culioli's theory and to the current state of the problem.

In fact, each current state of the problem can be situated on the diagram in two ways: first, referring to the position implied by starting terms and aggregates; second, taking into account the modifications of this first position due to modal terms and to the history of previous states. Then we cognitively interpreted the enunciative operations underlying these modifications. For example, it was possible to characterize:

1) The states where the subject anticipates that everything goes well or goes wrong, marked by the modification *p-p!* and positive versus negative interjections.
2) The states where an internalization is broken from material context, or where the externalization leads to a reunification or a sticking marked by the material context, with the modification *pp'-p!*.
3) The states where the subject identifies a constraint or only its existence without understanding its nature, marked by the modification *p'-pp'* and positive or negative evaluations.

Finally, it is only when the path reaches again the situation *p* after a loop, that the modifications disappear, giving rise to stabilizations and to the understanding of the constraints of the task.

Declarative-procedural interactions

Our approach takes semiotic aspects into account at the level of lexical choices, establishing functional meanings from their differentiations and giving them the status of linguistic markers. For example, the criterion based on the "repetition" of a lexical choice, already mentioned above, contrasts with any change in this lexical choice referring to the same object. That led us to a functional semiotic distinction between declarative and procedural aspects, as classically defined [1]. Therefore procedural aspects may appear at the declarative level, and declarative aspects at the procedural level. Then dynamical interactions between declarative and procedural levels may be conceived in the line of Cellerier [6].

The criterion we chose in our data was to consider the operations of location between moved objects as being at the declarative level, and the operations of

location between the places where the objects have to be moved at the procedural level. Then, in our above examples, the repetition *the green disk* between the naming of disks defines a declarative aggregate, and the repetition *on peg C* between the naming of pegs to which disks have to be moved defines a procedural aggregate [2], [3], [4].

Then different kinds of aggregates can be defined at declarative and procedural levels [3]. That allows an on-line identification of the specific construction of chunks, and aggregates, at both declarative and procedural levels. They can be generalized by internalization and externalization at both levels, but they do not develop at the same time [2], [3], [4].

6. CONCLUSION

In this paper, we presented some of our data and the theoretical background underlying them suggests a possible way integrating several areas, namely research, education, and problem solving.

In fact, these data have to be considered as belonging to an exploratory research. Many other results have to be discovered in this line. The theoretical background must be developed. Other criteria in order to grasp micro-cognitive-processes must be developed too. Furthermore, our approach was mainly directed toward an integration of language. But many issues beyond language must be developed.

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