A Dynamic Approach of Information in a Learning Task

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ABSTRACT

A new theoretical and methodological approach of the processing of information is presented. On line modifications in the structure of information, such as stretched, broken, re-unified, or stuck pieces of information can be characterized from linguistic markers. For that two kinds of detachability from the situation are analyzed in a cognitive interpretation of Culioli's enunciative model. On one hand, the detachability linked to *starting terms* has for criterion the anaphora. It marks the categorization of external aggregates of information, their internalization, re-inscribing them at a subjective level, and their externalization, re-inscribing them in the spatio temporal environment. On the other hand, the detachability linked to modal terms marks a strategic reorganization of information. Both kinds of detachability are modelled by Culioli's diagram involving different levels between parameters *S (subjective space)* and *T (temporal space)*. The passages from one of these levels to another follow specific routes with loops and strange loops. This paper analyzes the modification of information at the highest subjective level in the verbal protocol of a 10-year-old solving the Tower of Hanoi puzzle for the first time. The generalization to other tasks and to interaction between intelligent agents results from the interactive characteristics of linguistic markers.

Keywords. information processing, decision making, linguistic markers, anaphora, modal terms, attentional focusing, problem solving.

1. INTRODUCTION

Many attempts have been done to contextualize information [8]. But the way transmitter/receiver interaction is conceived is still very simplistic. It remains generally conceived from a mathematical point of view or from a literal approach to communication and language [5], [1], [9], and should benefit from recent developments in cognitive linguistics [7], [4]. In a previous paper [2], it was shown that several enunciative operations could be interpreted in terms of cognitive processes, so as to identify two distinct decision processes from linguistic markers. One of them, an internal decision process, re-inscribes information at several subjective levels of control, while the other, an external decision process, structures information in the spatio-temporal environment. Both processes interact for constructing new units of information, notably aggregates.

The purpose of the present paper is to formalize qualitative and structural changes in information from linguistic markers. For that, the verbal protocol of a 10-year-old child solving the Tower of Hanoi puzzle (*ToH*) for the first time was chosen in spite of the fact that this task is a very specific one, involving a priori no interactive process. Indeed, our method of analysis relies on an inter-subjective view of language which is always at work even in monologues. Furthermore, hints to extend the analysis to other situations have already been given, notably in the case of chess, and of representations distributed among intelligent agents [2], [10].

2. THE TOWER OF HANOI PUZZLE (*ToH*)

The task.
Four coloured wooden disks of decreasing size are initially placed on peg A (cf fig. 1). The goal is to move every disk to peg C so as to obtain the same configuration. Furthermore, two constraints have to be taken into account: not to move a disk on a smaller one; not to move a disk on which another one is laying.

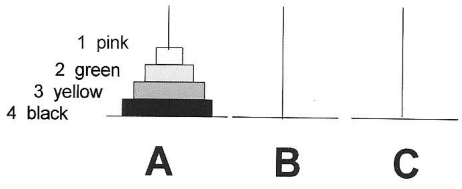

Fig 1 : Configuration of 4-disks Tower of Hanoi: initial situation
Goal: move all disks to C with the same configuration

The verbal protocol.
The verbal protocol of a novice 10-year-old was tape-recorded during her solving process four consecutive times. This paper focuses on the analysis of her first trial. The verbal protocol is presented in Table 1, and its analysis in Table 2.

Table 1. Verbal protocol.

L1 - I think I know but I am not sure at all ....number one I put it in the second one	34/1/-
L2 - oh well no there is a problem if I do that ...number two I put it in the third one	34/1/2
L3 - oh er no I won't do like that	234/1/-
L4 - the pink one I put it in the last one	234/-/1
L5 - the green one in the second one	34/2/1
L6 - then I put back the pink one it is allowed to be moved in the second one	34/12/-
L7 - then I put number three here at last in the third one	4/12/3
L8 - then so there I am blocked ...I want to put it there so er I will do like that	34/12/-
L9 - well I will put it in the third one the yellow one	4/12/3
L10 - er the pink one too	4/2/13
L11 - then er the pink one is it allowed to be put back to the first one *Exp {yes}* so I put it back to the first one	14/2/3
L12 - oh no ... yes I put it back to the first one er hem the green one I put it to the third one	14/-/23
L13 - then I put back the pink one to the second one	4/1/23
L14 - oh I am completely blocked no I put back the green one here	24/1/3
L15 - I put back the pink one to the first one	124/-/3
L16 - really I believe I have found but that must be... so the pink one I put it to the third one	24/-/13
L17 - then I...number two I put it to the second one	4/2/13
L18 - then number one I put it to the second one	4/12/3
L19 - the yellow one I put it to the first one	34/12/-
L20 - no it's dead difficult er the yellow one in the third one	4/12/3
L21 - the pink one in the third one too	4/2/13
L22 - number one but no because I want to succeed there	4/12/3
L23 - oh yeah but I want to succeed to get number three here then I believe that I have found this way then here	14/2/3
L24 - here	14/-/23
L25 - then the pink one in the last one too	4/-/123
L26 - the black one in the second one	-/4/123
L27 - er the..and then I can do it again this way the pink one in the first one	1/4/23
L28 - the green one in the second one	1/24/3
L29 - hem the pink one in the second one	-/124/3
L30 - the yellow one in the last ...first one	3/124/-
L31 - the pink one in the first one	13/24/-
L32 - it won't work no the green one in the last one	13/4/2
L33 - er yes so the pink one in the second one	3/14/2
L34 - the green one in the first one	23/14/-
L35 - the pink one in the...in the first one	123/4/-
L36 - the black one in the last one	123/-/4
L37 - the pink one in the last #er oh yes the pink one in the second one	23/1/4
L38 - the green one in the ...no the green no the pink one in the last one	23/-/14
L39 - that does not matter the green one in the second one	3/2/14
L40 - the pink one in the second one	3/12/4
L41 - the yellow one to the last one	-/12/34
L42 - the pink one to the first one	1/2/34
L43 - the green one to the last one	1/-/234
L44 - and the pink one to the last one	-/-/1234

34/2/1 means that disks 3 (yellow) and 4 (black) are on peg A, disk 2 (green) on peg B, disk 1 (pink tiny disk) on peg C

3. LINGUISTIC MARKERS

Enunciative operations formalize in terms of oriented relations the steps by which information is reorganized in order to construct utterances.

External aggregates of information.
Each oriented relation *aRb* is conceived as a basic *operation of location* [Fr. *repérage*], locating the locatum *b* relative to the locator *a*. It is cognitively interpreted as an attentional focusing on the locator *a*, automatically followed by *b*, in the line of Langacker [7], [2].

The basic operation of location within a proposition can be extended to a location between two propositions, and applied to the verbalization of two consecutive moves in a problem solving task, here in the case of *ToH* [2]. Then, situational location between moves or between disks can be characterized, the criterion for recognizing them being the repetition of the naming of pegs or of disks. In Table 1, the repetition *the second one*, in lines L5-L6, for the naming of pegs marks the construction of a situational aggregate of moves *m(2)⇒ m(1)*, locating the move of disk 1 relative to the focused move of disk 2. If in L6, the participant had said *on the green one* instead of *the second one*, the repetition would have been about disks, constructing the situational aggregate of disks *2⇒1*, disk *2* being focused and automatically followed by disk *1*. Aggregates of moves structure information at the procedural level, aggregates of disks at the declarative level [2].

Internal aggregates of information.
Starting Terms, marked by an anaphora, imply a process of detachment from the situation, giving access to abstraction, but narrowing and modifying it to reconstruct notional classes in the situation. In the above examples, in L6, L11 and L12, the anaphora *it* refers to *the pink one*. It marks that disk 1 has the status of *Starting Term*, quoted <1>.

Starting Terms are cognitively interpreted as the markers of an internal decision, which re-inscribes information at different levels of control. At a first level of control they mark a categorization of external occurrences. In L17, the starting term <2> (marked by anaphora *it*) categorizes the situational location *m(2)⇒ m(1)* (marked by the repetition *the second one*) and re-inscribes it as *<m(2)⇒ m(1)>* at the internal level. But in L6 the categorization associated to the starting term *<1>* is reduced to itself in the external space, without any internal effect [2]. At a second level of control, internal locations between starting terms can be found. The criterion for recognizing an internal location is that the repetition of the naming of pegs or of disks is due to an extension of the verbalization of a move to the anticipation of the following move, or to a return toward the previous one. In L11 and L12, the internal aggregate of moves, quoted *m<1>⇒ m<2>*, is marked by the repetition *the first one* which results from an extension of the move of 2 as a return on the move of 1.

Internal aggregates allow to simplify the global representation. They can be articulated together and with categorized external aggregates. If the temporal direction of these articulations is from the external space toward the internal one, it marks a process of internalization. If it is from the internal space toward the external one, it marks a process of externalization.

Modal terms
Modal markers imply a strategic detachment from the situation to recover information at other levels and to reorganize the ongoing situation. They are the markers of intended reorganizations along a fictive route toward a goal, in order to inscribe them in space and time. They imply a dissociation between automatic vs strategic processes: for the planning, marked by modal verbs such as *want*, *allow*, *can*; for retrieval from memory, marked by evaluations with or without modal terms; for storage in memory, marked by interjections such as

oh, *no*, *oh yeah*; for passing across a border, marked by interjections such as *well* [3].

4. THEORETICAL ASSUMPTIONS

Culioli's diagram

The specificity of this paper is to consider two kinds of detachments, one marked by *Starting Terms*, the other by modal markers, and to place them on Culioli's diagram (see fig 2). Indeed this diagram allows:

1) First, to distinguish among several levels of detachment from situation *p*: *p'* being the exterior of *p*, i.e. everything other than *p*; *pp'* involving a detachment from both *p* and *p'*, both considered as possible; *pp'** being another detachment and a differentiation from *pp'*, leading to reassert a new situation among possible *pp'*.
2) Second, to specify obligatory passages from one level of detachment to another one. These passages formalize the status of the reorganized information, and may lead to loops (from *p* toward *p'* and then toward *pp'*, with a possible return toward *p* or *p'*), or to "strange loops" [5]. A strange loop starts from *p*, toward *p'*, then *pp'*, then *pp'**, and finally delimits *p* at the level of *pp'*. This demarcation may involve several returns from *pp'* to *pp'** with returns back from *pp'** to *pp'*, in order to categorize and to establish demarcations among possible occurrences in *pp'*, and so to delimit occurrences of *p*.

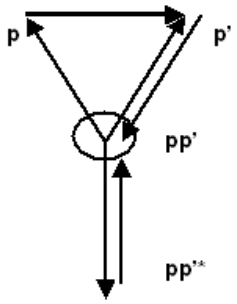

Fig. 2. Culioli's diagram

The initial set *(p, p')* depends on space and time (*T*) and on the intention of the utterer (*S*). The position *pp'* may give rise to a scanning of possible occurrences. The position in *pp'** and its return to *pp'* may homogenize the scanned occurrences. It may also keep or reject some of them so as to re-delimit *p* within *pp'*. Furthermore, an occurrence may be chosen at random in the set of occurrences, either as one but possibly another, or as the obligatory occurrence. The position of the successive occurrences on the diagram may account for these changes of status.

Cognitive interpretation

An external decision process is initially defined as operating in space and time *T*, and positioned in *p* on Culioli's diagram. An internal decision process, detached from *T*, is operating in *S*, and positioned in *pp'* on Culioli's diagram; *p'* is the exterior of the situation *p* in *T*; *pp'** the exterior of *pp'* in *S*.

The introduction of detachments marked by modal terms introduce modifications in the status of decision processes. Our intent is to focus the present study on the cases where decision processes are positioned in *pp'**.

An external decision process, firstly associated with parameter *T*, can be modified so as to become associated with parameter *S* and to be placed in *pp'** on Culioli's diagram. This modification entails a translation of the current instant t_0 toward a fictive instant t'_0 which can be placed relatively to t_0, either in the past or in the future. If t'_0 is placed in the past of t_0, past occurrences are considered as being a dead end relatively to the goal. If t'_0 is placed in the future of t_0, future occurrences are considered as already done. Then, criteria have to be elaborated in order to choose between these two cases. For that, positive or negative interjections which mark a high degree in Culioli's theory, can be used. Then, negative interjections will mark the storage in memory that the already done steps lead to dead ends, and positive interjections that the expected future steps are considered as already done. The absence of interjection can be interpreted as the coincidence of t'_0 with t_0, then it marks that nothing can modify the decision.

An internal decision process, firstly associated to parameter *S*, can be modified and placed in *pp'**. It will mark that fictive relations entail modifications in the set of possible occurrences. Furthermore, according to our theoretical background, three cases have to be distinguished:

- Specific effects arise when the internal decision in *pp'** is linked to an internal aggregate. An internal aggregate placed in *pp'** will become independent from the external space; then, the primary information appears as broken into an external part and a fictive point of view provided by the aggregate.
- An external aggregate categorized by a starting term will resist to that independence when placed in *pp'**; then pieces of information are stretched by their fictive point of view without being broken, when internalized; both are re-unified after having been broken, or stuck together when externalized.
- The starting term without any aggregate categorizes nothing but itself. Then everything is as if no categorization had been operating, and as if there were no fictive relation except the ones which are already in the external space.

Our assumption is that the analysis of the modified decision processes involved in the successive moves of disks in *ToH*, will bring useful insights on information processing. The above cognitive interpretation will allow to characterize the steps judged bad or already done, the steps where pieces of information are stretched, broken, re-unified, or stuck together, and the steps where arises a fictive reorganization of the set of occurrences.

5. METHOD

The co-occurrence of the two kinds of detachments, respectively marked by *starting terms* and *modal terms* in the verbalization, may be placed on Culioli's diagram for each successive move of disks. The analysis of the verbal protocol is presented in Table 2. The unit of analysis is the verbalization of a move. The notations used for the analysis are explained hereafter.

Decision processes

External decision processes, quoted d_E, and internal ones, quoted d_I, are operating in different ways according to the status of the moved disk *i* (external disk, or disk having the status of a starting term, quoted <*i*>), and to the status of the aggregate in

which disk *i* may be involved (external aggregate, categorized or not by a starting term, or internal aggregate). Then, their notations are differentiated as follows:

d_E *(i)*: external decision process for moving disk *i*;
d_E *(m(i))*: external decision process for moving disk *i*, itself involved in external aggregates *m(i)⇒ m(j)* or *m(j)⇒ m(i)*;
d_I *(i)*: internal decision for <*i*>, i.e. for moving disk *i* which has the status of a starting term;
d_I *m(i)*: internal decision for <*i*>, *i* having the status of a starting term, when involved either in external aggregates <*m(i)⇒ m(j)*>, categorized by the starting term <*i*>, or <*m(j)⇒ m(i)*>, categorized by the starting term <*j*>, or *m(j)⇒ m(i)*, not categorized by disk *j* which has not the status of a starting term.

Their position on Culioli's diagram are conceived as follows:

- d_E *(1)* and d_E *(m(1))*, are both placed in *p*, both being external decision processes.
- d_I *(i)* is positioned in *p*. Indeed, this internal decision process categorizes nothing except disk *i* itself; its effects are considered as remaining in the external space [2].
- d_I *(m(i))* is positioned in *p'* as a first level of detachment from the situation, which remains highly linked to the external space by external aggregates.
- d_I *(m<i>)* is positioned in *pp'*, as internal decision process.

Modal Terms
Strategic (vs automatic) goals and evaluations, marked by a modal term (vs no modal term) are quoted as follows:

<goal>: strategic goal (goal with modal verb)
goal (without angle brackets): automatic goal (no modal term)
<ev>: strategic evaluations (evaluation with a modal term)
ev. : automatic evaluations (evaluation with no modal term)
<int>: interjection (mark of strategic storage in memory)
<well>: mark of strategic passage across a border

Strategic elements, marked by a modal term, involve a detachment from the situation. These detachments are considered as modifying the position of decision processes on Culioli's diagram. and for example, quoted Md_E *(i)*, Md_I*(m(i))* in case of one modification, and MMd_E *(i)* in case of two simultaneous modifications.

History of positions on Culioli's diagram
Our intent is to take into account, for each disk, the history of the modified decision processes of its successive moves along the solving process. For that the positions on Culioli's diagram of decision processes (see above), have to be modified, for each disk, according to the position associated to its previous move. Some examples of these modifications are presented hereafter (cf. Table 2):

- in L3, MMd_E*(2)* for which d_E*(2)* alone would be placed in *p*, will bring two steps of modifications linked to modal terms <*int*> and <*ev.*> to the previous move of disk *2*, in L2. So, it will be placed in *pp'**.
- in L4, d_I *(1)* would be placed in *p*, but the placement in *p* does not modify the previous placement of disk *1*, in L1. So, in L4, the position will remain the same, in *p'*, than the position in L1.
- in L11, Md_I*(m<1>)* for which d_I*(m<1>)* would be placed in *pp'*, shows in fact three levels of modifications (two for *pp'*, and one more due to the modal term <*move 1 to A*>), which have to be added to the position *pp'* of the previous move of disk *1*, in L10. So, its final position results from: one modification for going from *pp'* toward *pp'**, one more for going from *pp'** toward *pp'*, and the last for going again from *pp'* toward *pp'**.
- in L13, d_E*(1)* would be placed in *p*. But it arises after the placement of Md_I *(m<1>)* in *pp'**, in L11, so it will be placed in *pp'*.

6. ANALYSIS OF THE PROTOCOL

The analysis of the protocol is presented in Table 2. Preliminary reports, non presented here, showed that the first strategic goals were <*get off 123*>, <*get off 4*>, <*put 123 on 4*>. They are used to partition the solving process and to clarify the results. Furthermore, according to the purpose of this paper, only the results about the placement in *pp'** are discussed. These placements appear only for disks *1* and *2*.

Goal < *get off 123* >
Two positions of external decision processes appear in *pp'** during the achievement of this goal:

- in L3, for disk *2*, with the external decision MMd_E *(2)*, and with the negative interjection *oh no*. So it marks that the situation is considered as a dead end. This gives rise to a change of the chosen occurrence, as illustrated by the placement in *pp'*, in L4 and L6, in order to modify the strategy. Disk *1* is placed on the other peg of the initial set of occurrences *(1B, 1C)*. This gives rise to a new possible occurrence for disk *2*, placed on peg *B* instead of peg *C*.
- in L6, for disk *1*, with the internal decision Md_I *(m(1))*, categorizing *m(1)*, the non focused part of the external aggregate *m(2)⇒ m(1)*. It constitutes the first step of the process of internalization of the procedural information *m(1)*, and stretches the external information about *disk 1* toward gaining some independence but without breaking it into pieces. The fictive procedural relation between disk *2* and disk *1* falls under attentional focusing in the external space and entails the move of disk *1* on disk *2*. That allows to achieve the first subgoal <*get off 123*>.

Goal < Get off 4 >
The participant wants to move disk *4* to peg *C*. But the goal is really <*get off 4*>. That will be achieved two times, first by moving *4* to peg *B*, and second by moving it to peg *C*. The positions in *pp'** can be seen as follows:

- in L11, for disk *1*, with the internal decision Md_I *(m<1>)*, followed by *m<2>* by means of the internal aggregate *m<1>⇒ m<2>*. It marks the internalization of *m(1)*, and the independence of *m<1>* from the external space. Therefore, information about disk *1* is broken into an external part and an internal procedural point of view involved in *m<1>⇒ m<2>*. It marks a fictive extension of the set *(1B,1C)* by means of *1A*. Then a scanning of the possible occurrences will start.
- in L17, for disk *2*, with the internal decision d_i *(m(2))*. It involves a step in the process of externalization of aggregates *m<1>⇒ m<2>* and <*m(2)⇒ m(1)*> in order to

Table 2 . Analysis of the verbal protocol

Lines	States	<ST> Disks	Locations	Goals Evaluations	Decisions	Positions on fig..2	Action	Possible actions
L1	234/1/-	<1>		<ev.>	Md_I (1)	p' (1)	1B	/ (1B, 1C)
L2	34/1/2	<2>		<ev.>	Md_I (2)	p' (2)	2C	/ (2C)
L3	234/1/-	2		<int.><ev>	MMd_E (2)	pp'* (2)	2A	/ (2A)
L4	234/-/1	<1>			d_I (1)	p' (1)	1C	/ (1B, 1C)
L5	34/2/1	2	m(2)⇒ m(1)		d_E (m(2))	pp' (2)	2B	/ (2B)
L6	34/12/-	<1>		<move 1 to B>	Md_I(m(1))	pp'* (1)	2B⇒1B	/ (2B⇒1B)
L7	4/12/3	3			d_E (3)	p (3)	3C	/ (3C)
L8	34/12/-	<3>		ev. <goal>	Md_I (3)	p' (3)	3A	/ (3A)
L9	4/12/3	3		<well>	Md_E (3)	pp' (3)	3C	/ (3C)
L10	4/2/13	1			d_E (1)	pp' (1)	1C	/ (1B, 1C)
L11	14/2/3	<1>	m<1>⇒ m<2>	<move 1 to A>	Md_I (m<1>)	pp'* (1)	1A	/ (1A, 1B)
L12	14/-/23	<2>		<int.><int>	MMd_E (m<2>)	pp' (2)	1A⇒2C	/ (1A⇒2C)
L13	4/1/23	1			d_E (1)	pp' (1)	1B	/ (1A, 1B)
L14	24/1/3	2		<ev> <int>	MMd_E (2)	pp' (2)	2A	/ (2A)
L15	124/-/3	1			d_E (1)	pp' (1)	1A	/ (1A, 1C)
L16	24/-/13	<1>		<int> <goal>	MMd_I (1)	pp' (1)	1C	/ (1A, 1C)
L17	4/2/13	<2>	<m(2)⇒ m(1)>		d_I (m(2))	pp'* (2)	2B	/ (2B)
L18	4/12/3	<1>			d_I (m(1))	pp'* (1)	2B⇒1B	/ (2B⇒1B)
L19	34/12/-	<3>			d_I (3)	pp' (3)	3A	/ (3A)
L20	4/12/3	3	m(3) ⇒ m(1)	<int> <ev.>	MMd_E (m(3))	pp' (3)	3C	/ (3C)
L21	4/2/13	1			d_E (m(1))	pp' (1)	3C⇒1C	/ (3C⇒1C)
L22	4/12/3	1		<int><goal>	MMd_E (1)	pp' (1)	1B	/ (1B, 1C)
L23	14/2/3	1		<int><move 3 on Y> <ev.>	$MMMd_E$ (1)	pp'* (1)	1A	/ (1A, 1C)
L24	14/-/23	2			d_E (2)	pp' (2)	2C	/ (2C)
L25	4/-/123	1			d_E (1)	pp' (1)	1C	/ (1B, 1C)
L26	-/4/123	4			d_E (4)	p (4)	4B	/ (4B)
L27	1/4/23	1		<goal>	Md_E (1)	pp'* (1)	1A	/ (1A, 1B)
L28	1/24/3	2	m(2)⇒ m(1)		d_E (m(2))	pp' (2)	2B	/ (2B)
L29	-/124/3	1			d_E (m(1))	pp' (1)	2B⇒1B	/ (2A⇒1C)
L30	3/124/-	3	m(3)⇒ m(1)		d_E (m(3))	p (3)	3A	/ (3A)
L31	13/24/-	1			d_E (m(1))	pp' (1)	3A⇒1A	/ (3A⇒1C)
L32	13/4/2	2		ev. <int>	Md_E (2)	pp'* (2)	2C	/ (2C)
L33	3/14/2	1		<int>	Md_E(1)	pp'* (1)	1B	/ (1C)
L34	23/14/-	2	m(2)⇒ m(1)		d_E (m(2))	pp' (2)	2A	/ (2A)
L35	123/4/-	1			d_E (m(1))	pp' (1)	2A⇒1A	/ (2A⇒1C)
L36	123/-/4	4	m(4)⇒ m(1) m(4)⇒ m(2)		d_E (m(4)) d_E (m(4))	p (4) p (4)	4C 4C	/ (4C) / (4C)
L37	23/1/4	1	m(1)⇒ m(2)	<int>	Md_E(m(1))	pp'* (1)	1B⇒2C	/ (1C⇒2B)
L38	23/-/14	1		<int><int>	MMd_E (1)	pp'* (1)	4C ⇒ 1C	/ (4C⇒1B)
L39	3/2/14	2	m(2)⇒ m(1)	ev.	d_E (m(2))	pp' (2)	4C ⇒2B	/ (4C⇒2C)
L40	3/12/4	1			d_E (m(1))	pp' (1)	2B ⇒1B	/ (2B⇒1C)
L41	-/12/34	3			d_E (3)	p (3)	3C	/ (3C)
L42	1/2/34	1			d_E (1)	p (1)	1A	/ (1C)
L43	1/-/234	2	m(2)⇒ m(1)		d_E(m(2))	p (2)	2C	/ (2C)
L44	-/-/1234	1			d_E (m(1))	p (1)	2C ⇒1C	/ (2C⇒1B)

234/1/- means that disks 2, 3, and 4 stand on peg A, disk 1 on peg B, no disk on peg C.
<1> means that disk 1 is in position of a starting term (ST); <ev> means a strategic evaluation; <goal> means a strategic goal;
<int> interjection; <well> means interjection *well*; d_I (i) internal decision for disk i; d_E(m(i)) external decision for *m(i)*
See other notations in the text.

construct the class *m(1)⇔ m(2)*. It marks that *m(2)*, positioned in *pp'* in *m<1>⇒ m<2>* , and in *pp'** in *<m(2) ⇒ m(1)>* are stuck together. Then, there is a procedural coordination between the move of disk 2 following disk *1* (due to *m<1>⇒ m<2>*) and its move followed by the move of disk 1 (due to *<m(2) ⇒ m(1)>*).

- in L18, for disk 1, with the internal decision *d_I (m(1))*. It marks the re-unification of the two parts of disk *1*: disk *1*, whose *m(1)* constitutes an extension in the external space, and its broken part *m<1>*, internal point of view involved in *m<1>⇒ m<2>*. Then, the re-unification of these two parts, both at level pp'*, constitutes another step in the construction of the class *m(1)⇔m(2)*, and the homogenization of the scanned three possible places for the move of disk 1. It means that two possible occurrences may be attributed to each of these places.
- in L23, for disk 1, with the external decision MMMdE (1) and the positive interjection *oh yeah*. It marks that it is already done. It is sufficient to reverse the hierarchy between goal *<take off 4>* and subgoal *<move 3>*, i.e. to move disk *4* before moving disk *3*. Then direct links between the moves of disks *1* and *2* and the move of disk *4* are constructed.
- in L27, for disk *1*, with the external decision *Md_E(1)*, without interjection. It marks that there is nothing else to do to achieve the subgoal *<move 3>*. The solution consists in one of the three homogenized places of disk *1* and in the set of the two possible occurrences attributed to this place, whatever the place of disk *1*.
- in L32, for disk *2*, with the external decision *Md_E (2)* and the negative interjection *no*. It marks that what has been done is a dead end. It rejects the chosen place of disk *1* because it led disk *2* to a place that did not fit the goal. In fact disk *2* is going to peg C instead of disk *4*.
- in L33, for disk *1*, with the external decision *Md_E (1)* and the positive interjection *yes*. The placement of disk *1* has been done according to the placement of disk *2* in order to achieve the goal *<get off 4>* with disk *4* on peg *C*, but without a true anticipation of its suitable place. But, it does not matter if the place to which disk *2* was gone does not fit the goal. In fact, in this case, it is sufficient to take the other place for disk *1* so that disk *2* may come to the right place.

Goal <Put 123 on 4>

Two positions in *pp'** occur during the achievement of this goal, in L37 and L38, for disk *1*. In L37, the external decision *Md_E(m(1))* and the positive interjection *oh yes* mark that it is already done. Nevertheless, the place where disk *2* has to go remains partly anticipated. In fact, as shown, in L38, with the decision *MMD_E(1)* and the two negative interjections *no*, it is

still necessary to move disk *1* before anticipating the suitable place of disk *2*. So, disk *1* goes to its other place without having to move disk *2*. Finally, *p* is reconstructed within *pp'*, achieving the construction of a strange loop for both disk *1* and disk *2*, but only in the context of the last three moves, in L42-44.

6. MAIN RESULTS

Beyond the fact that substantial changes can be identified in the solving process from the cognitive interpretation of linguistic markers and of enuntiative operations, several important results, all of them obtained from the analysis of the placement in pp'*, are worth underlining:

1) Modifications in the structure of information, such as stretched information, broken information, re-unified information, may be characterized from linguistic markers. More precisely, these modifications are marked by the conjunction of the position in *pp'**, on Culioli's diagram, with the steps that involve a process of internalization and externalization. This paper showed the consecutive modifications of the broken information associated to disk *1*, while information associated to disk *2* was not broken (the component *m(2)* was not placed in *pp'** when internalized).
2) Progressive structures of information in order to construct elementary classes may also be characterized from linguistic markers. This paper showed the articulation of two aggregates, an external one categorized by a starting term $<m(2) \Rightarrow m(1)>$, and an internal one $m<1> \Rightarrow m<2>$, the component *m(1)* being at the same level *pp'** in both aggregates. It showed also that different levels of detachability *pp'* and *pp'** both available for the same component *m(2)*, are stuck together. These two structures intervene as steps in the progressive construction of the elementary class $m(1) \Leftrightarrow m(2)$, that will end when reconstructed at level *p*.
3) The set of alternative actions associated with a given piece of information can be extended. In this study, the first set of occurrences *(1B, 1C)*, associated with disk *1*, was extended by a fictive occurrence, *1A*. The three possible occurrences for disk *1* were homogenized only later. Furthermore, it is possible to fictively increase a set of possible but constrained occurrences by means of other elements. For example, the position of disk *2* in *pp'*, in L5, after having been in *pp'**, in L3, showed an extension of its single possible occurrence by means of a change of placement of disk *1*.
4) The change of status of the set of occurrences and of the chosen action in this set can be characterized. In this paper we showed that the set of the two possible occurrences for disk *1* remained at first linked to the initial peg. It is only later, on two occasions in L11 and in L18, that it was decontextualized and extended to any peg. Furthermore, it is only from L27 that the solution of the problem is attached to this decontextualized set. Nevertheless, the choice of one or another occurrence remains still a random one. It is only from L33 that the choice of one of the two occurrences is made instead of the other; but only in L37 that this choice begins to anticipate the constraints of the goal; and only at the end of the problem that *p* achieves the strange loop for disk *1*.

7. CONCLUSION

In this study, information coming from memory or from environment is conceived as always reconstructed when used in the context of a specific goal. Our results show that a learning task involves a complexity which is largely beyond the possibilities given by classical approaches. A double level of interpretation underlies the above analysis, first linguistic forms as markers of enunciative operations, second a cognitive approach of enunciative operations, the closest possible to their logical definition. Then, on line modifications in the structure of information which can be stretched, broken, re-unified, but also articulated, or stuck, can be characterized from linguistic markers in some specific but well defined contexts. Taking them into account could renew the concept of information and the processes of simulation in the problem solving area.

The results were about procedural aggregates of moves, but in a similar way they could concern declarative aggregates of disks, and the articulation of declarative and procedural aggregates progressively re-unified. More generally, these results can be extended to more complex tasks and to interactive agents by means of aggregates of various objects, of various actions, and of relations among agents [2], [10].

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