Non Verbal Communication Devices and Language Acquisition or Re-acquisition

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Abstract
The author is a mathematician, trained in logic and recursion theory. When confronted to the needs of children in special education (behavioral problems, mental retardation, x-fragile syndrome, language disorders) he naturally decided to use logico-mathematical tools with them. He created an adapted methodology to use these tools in a nearly non verbal way. This new approach is called the "Non Verbal Communication Device" approach (NVCD). The purpose of this chapter is to describe and define the NVCD like approaches, the cognitive observations realized with them and then to try to answer the question "Why does it work ?"

Keywords: Non Verbal approach, Logic, Recursion, Language, Handicap.

1 Introduction

In order to study and favor cognitive development, we defined a new approach (Lowenthal, 1980, 1983) : the concept of Non Verbal Communication Device (NVCD).

In this paper we will first explain what led us to the elaboration of this new approach. We will then define the notion of NVCD like approaches, and give two examples. Results of researches based on the use of these approaches in clinical and experimental settings will also be presented. This will lead us to a natural question : "Why does it work ?"

In order to try to suggest an answer to this question, we will have to make a short detour via researches concerning the structure of the natural human language function and the relations of this human property with the principle of recursion and with Neural Networks. This will finally lead us naturally to the description of a new research project.

2 Preliminary observations

We tried to use what was then considered as "new math" approaches, based on the use of essentially non verbally presented problem-situations (Cordier and Lowenthal, 1973; Cordier et al., 1975) with handicapped children. The positive and unexpected results obtained led us to try to understand why it worked, while all other approaches had failed. We then used several mathematico-logic games such as Dienès' A-blocks or the Pegboard and the Dynamical Mazes (see below) using a new methodology to introduce the problem-situations. It became soon obvious that the most fruitful

International Journal of Computing Anticipatory Systems, Volume 28, 2014
Edited by D. M. Dubois, CHAOS, Liège, Belgium, ISSN 1373-5411 ISBN 2-930396-17-2

approaches were those that shared common technical (for the device) and methodological (for the approach) characteristics. These characteristics are at the basis of our NVCD concept.

3 A New Approach : The Non Verbal Communication Devices (NVCD)

Each NVCD type approach is the combination of a special intervention and observation method and of a specific device (Lowenthal, 1980).

The method is based on a quasi non verbal approach (the experimenter does not speak about the problem to be solved) and on manipulations by the subject of specific objects. This method enables the observer to create a mediator of representation and communication.

The specific device must be made of pieces which can easily be assembled in differing ways. These objects do not belong to the cognitive background of the subjects. They are provided with technical constraints. These constraints make certain actions possible and other impossible. This in turn suggests a logical structure to the subject. We present in the two following sections examples of such objects and associated exercises.

3.1 First example : The Dynamical Mazes

The Dynamical Mazes have been invented by Cohors-Fresenborg (1978). This device is made of a board provided with holes defining a grid and of different pieces which can be arranged on this board in order to make a network which is in fact the mechanical equivalent of an electronic finite automaton (figure 1). Cohors-Fresenborg's purpose in creating this tool was to introduce teenagers to the notion of algorithm. This author confronted his subjects verbally to word problems and asked them to construct "the network which represents the solution of the problem".

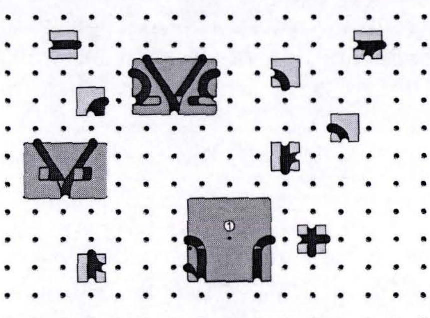

Figure 1 : The pieces, simple "rails", "switches" and "counter" created by Cohors-Fresenborg

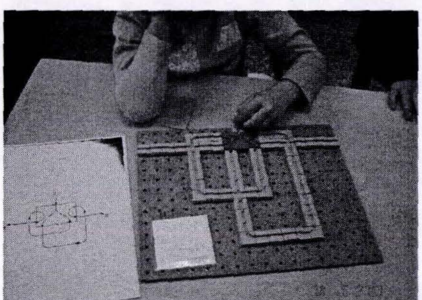

Figure 2 : A child while studying the network built according to the diagram placed to the left

We chose to use this material differently : we show the subject a diagram representing a network. We ask him to build it with the available pieces, to explore the regularities of the network he has built and finally to explain "what it is good for" : this is the inverse problem (figure 2). The method we use also enables the subject to discover the solution by working at the brunerian level which suits him best : enactive, iconic or symbolic representation (Bruner et al., 1966).

We used this device, among other things, in order to introduce mentally retarded subjects to the meaning of the "If ... Then ..." structure and to all other logical connectives.

Our approach can be used to introduce non recursive but also slightly recursive and fully recursive exercises. The relevance of this "recursive" dimension will be developed later.

3.2 Second example : the pegboard

The pegboard is a game for young children : it is made of a plastic base board provided with holes defining a grid in which the child can place color headed plastic nails. The nail heads can have different shapes, enabling thus the young child to make "nice drawings" on his grid. In our case, the nails are defined by two variables : the shape of the head (square or quarter of a circle) and the color (blue, yellow, red, green, white, purple or orange). In order to let the reader have a better understanding, the nail colors are represented by the initial of the color name. These letters are placed in the following figures (except for figure 4). We also chose to use the term "triangle" to represent a nail with a quarter of a circle as head and we represent it by a triangle in the ensuing figures.

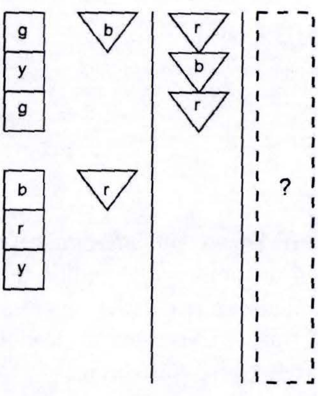

Figure 3 : the execution of a program

Figure 4 : two children working together

We used this device to introduce a programming language based on concrete manipulations. This language, inspired from Logo, is accessible to very young children, handicapped (Lowenthal & Saerens, 1982, 1986) or not (Lowenthal et al, 1996). For this type of exercises we must divide the base board in three columns. The left one is reserved for sequences of square headed pegs assigned to a "triangle" which represent the name of the sequence, thus defining a procedure. The central column is reserved for "triangles" (those used to name the procedures): this is the program. The right column corresponds to the execution of this program (figure 3).

In order to introduce an exercise, we show the child a base board on which he can see two of the columns of nails and we ask him (without any other detail) to "make the missing one". Some exercises are easy like the plain execution of a program (figure 3). More complex exercises require the reconstruction of the program (figure 5) or the discovery of the procedures used (figure 6).

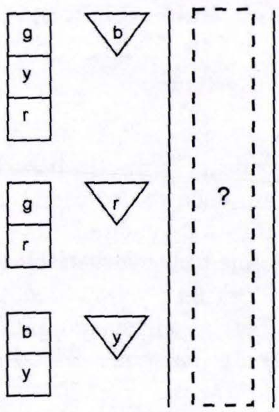

Figure 5 : reconstruction of the program

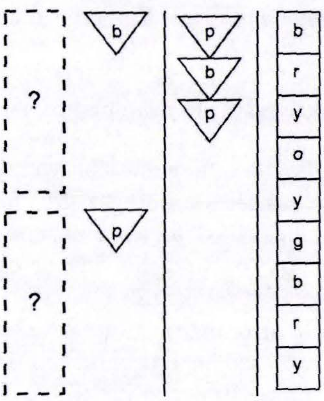

Figure 6 : discovery of the procedures used

4 Results observed after using NVCD like approaches

4.1 With normal subjects

4.1.1 Approach based on Dynamical Mazes Manipulations

Very curiously the use of a non verbal approach based on manipulations of Dynamical Mazes favors the acquisition of tasks linked to language : reading abilities (Lowenthal, 1986), a better knowledge of arithmetic facts and a better visuo-spatial organization in 6-year-old children (Lefebvre, 2002), and better verbal productions (Lowenthal, 1984 ;Yang, 2005) in 7 years old children who used this device when they were 6.

4.1.2 Approach based on Pegboard Manipulations

Very curiously also, non verbal manipulations of the pegboard by 1st and 2nd graders favor the production of more complex verbal productions (Lowenthal, 1990; Yang, 2005) and the acquisition of decoding (reading) abilities (Soetaert, 2003).

4.2 With handicapped subjects

4.2.1 NVCD type approaches used with young subjects

NVCD type approaches have been successfully used with young subjects with mental retardation, x-fragile syndrome, behavioral problems, dyslexia, autism or Asperger's syndrome. All clinical observations show that these approaches favor in these subjects the development of a more structured verbal communication system. The subjects submitted to this type of treatment behave in a less aggressive way; they are also able to spend more time solving exercises and exhibit longer concentration times (Bordignon et al., 2004, 2005; Bordignon and Vandeputte, 2005; Lowenthal, 2005; Lowenthal & Vandeputte, 2006).

NVCD type approaches have also been used with young subjects with a Non Verbal Syndrome. The research hypothesis was that the difference between a low Performance IQ and a relatively high Verbal IQ would be reduced after the manipulations implied by the NVCD type approaches. The results show exactly the contrary : the difference is augmented after treatment, in favor of the Verbal IQ (Mauro, personal communication)

4.2.2 NVCD type approaches used with patients with localized cerebral lesions

Clinical observations with such patients show that some, but not all of these patients can thus reconstruct a structured communication they lost (but not necessarily a verbal communication) and also some other superior cognitive functions (Lowenthal & Saerens, 1982, 1986).

5 Why does it work like this?

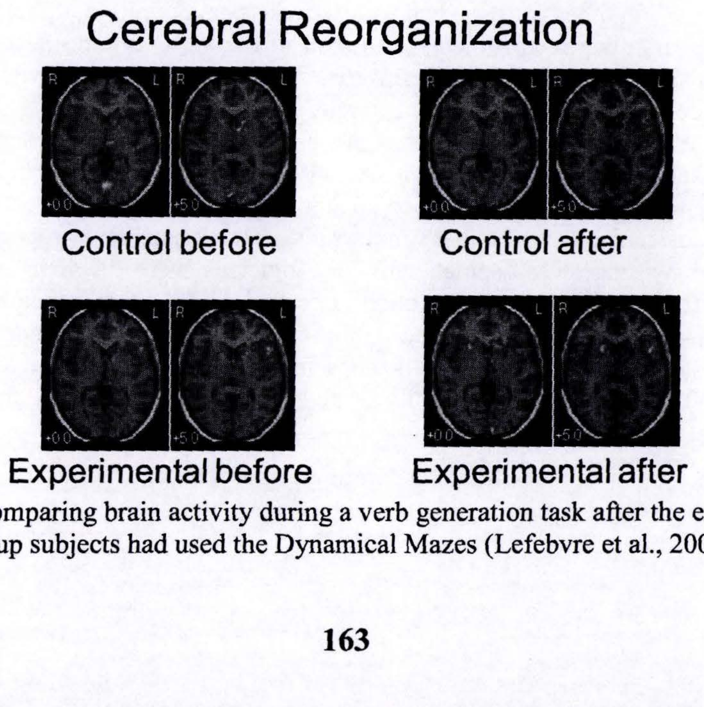

Figure 7 : comparing brain activity during a verb generation task after the experimental group subjects had used the Dynamical Mazes (Lefebvre et al., 2006)

All the results mentioned in section 4 suggest that NVCD like approaches, one way or another, favor the development of language related activities. But this raises a new question : why do non verbal approaches have this type of influence on language development or language re-acquisition ?

Our observations suggested a conjecture (Lowenthal, 1999): "the manipulations implied in NVCD like approaches could favor a cerebral reorganization".

Lefebvre et al. (2006) proved a milder form of this hypothesis. They let young adults manipulate Dynamical Mazes as described above and observed their cerebral activity using an fMRI observation. They showed that after the NVCD like manipulations, the subjects' brains used more neurons in the neighborhood of the basal ganglia, while theses subjects were engaged in a language task, as if the manipulations had helped them to become more efficient when confronted to language tasks.

These results suggest that NVCD like approaches have an influence on language acquisition or re-acquisition because they have an influence on the brain. This leads us to another question : why is it so ? what is the underlying mechanism that influences the brain organization ?

6 Language and recursion

Let us now make a short detour to examine some theories introduced by psycholinguists and other researchers in the field of language.

First we must remind the reader of the definition of the principle of recursion.

A basic philosophical principle forbids to use the concept we are defining, inside its own definition : we can say "a **table** is a flat horizontal slab or board, usually supported by one or more legs, on which objects may be placed, such a slab or board on which food is served" (Wordreference.com dictionary, 2012) but we will never say "a **table** is a **table** that … ". In other words, when we use a classical definition, the word or concept to define appears always as subject, to the left of the verb "**is**" and never to the right, embedded inside the core of the definition. A different approach would not define anything since it would lead to a vicious circle, and thus to a paradox.

Nevertheless there are exceptions : the principle of recursion enables us to do precisely what appears to lead to vicious circle without doing so, but this is only possible when the concept to be defined contains a notion of degree of complexity. This principle enables us to describe in a simple way complex cognitive processes which can be described by stages. Mathematicians and logicians were the first one to use the principle of recursion to clarify the notion of "calculability" : this principle allows us to use a concept or a function inside the definition provided that the concept or function we are in the process of defining is constantly used "inside" at a lower level of complexity. This type of situation is illustrated by the definition of the function f(n) as shown in table 1.

Table 1 : a definition by recursion

$$\mathbf{f\,(n+1) = 2^{f(n)} - 1}$$

$$\mathbf{f\,(0) = 2}$$

Is there any relation between this principle and our usual verbal language ? We often use short sentences, such as : "It rains" or "Could you please give me the salt ?" But we also use more complex sentences when we must specify about which specific object we are speaking : "The key is broken", taken out of its context, does not yield much information. We better specify "The door key is broken" or, if our house has two doors, it is better to say "The garden door key is broken". We could also consider the case of the lucky owner of two houses, one on Liverpool street and one on Oxford street : he should specify "The garden door of the Liverpool street house is broken", or better "The Liverpool street garden door is broken". The speaker could of course do all this by using short sentences, uttered one after the other : "The key is broken. It is the door key. The door is the garden door. The house is on Liverpool street" One would say in this case that the speaker expresses himself by ***concatenation***, i.e. by a simple juxtaposition of simple expressions. Unluckily, this process is neither elegant nor economic : we often prefer the use of expressions full of subordinates, and even full of nested subordinates. Apparently, French and English do not behave in same way. The embedded structures are frequent in English (or German) : there are sentences such as "The cheese the rat the cat killed ate lay in the house Jack built". The meaning of such a sentence is obvious for an English speaking person. A French speaker needs another type of structure based on the use of the passive voice and explicit relative pronouns such as : "Le fromage que le rat, qui a été tué par le chat, a mangé se trouvait dans la maison que Jack a construite". Mark Twain once mentioned that when we encounter a German sentence, we must first open a parenthesis "within which we find a big parenthesis within which we find a king parenthesis". According to this writer, the main part of the idea the sentence is meant to convey, resides in the extreme parts of the production, which implies a distance relation : in the sentence "The boy the girl Peter likes hates eats pizza", the main idea the speaker wants to convey is "The boy eats pizza", the rest of the sentence serves only to specify who exactly the actors are. When comparing an English and a French sentence, we must note that the French sentence is longer in number of words, but cognitively easier for our brain : the relatives are not as embedded as in the English equivalent and the use of the passive voice enables to reduce the cognitive load. Sentences with nested subordinates are rather frequent in English and in German, but not in Latin languages. It must be stressed that sentences with embeddings are more economical, as far as formulation is concerned, but that this economy implies a cognitive overload : even if we do not like them, we are able to understand them. The embedded relatives which we encounter in such sentences represent precisely an example of the use of the principle of recursion. Or is it an example of a reduced version of this principle ?

Why are such sentences so important ? And why should we think so much about recursion in verbal language ?

According to Hauser, Chomsky and Fitch (2002) there are two "Faculties of Language" : the first one is the "faculty of Language Broad sense" and we share it with non human animals ; the second one is the "faculty of Language Narrow sense" and is specific to human beings. This "Faculty of Language Narrow sense" comprehends the principle of recursion, which would thus be one of the specificities of human beings. Some authors (e.g. Premack, 2004) agree with Hauser et al. but many others (Pinker &

Jackendoff, 2005; Gervain et al., 2008; Hochmann et al, 2008) have a totally different opinion : according to them, the principle of recursion does not play an essential role in the human language. Since 2002 several researchers have conducted experiments yielding apparently contradictory results. Cotton-top tamarin apes seem to lack the possibility to recognize nested structures (Fitch & Hauser, 2004) but European starlings share with us the principle of recursion (Gentner et al., 2006). According to Levinson (oral communication during the Mons Conference on "Language and Recursion", 2011), human beings do not use more than 5 levels of embeddings.

It is thus not acceptable to claim that the full principle of recursion plays an essential role in the human verbal language function. Nevertheless, the examples quoted above show clearly that embedded structures play a certain role, which imply a certain mastery of "long distance" relations, as encountered in "If ... Then ..." structures. This type of mastery is required for the comprehension of sentences such as "If my car engine produces too much CO2 , then it is obvious that I will have to pay more car taxes". Similar remarks can be made about some interrogative or passive sentences. The main conclusion at this stage is that embedded structures and long distance relations are important for human verbal language.

While pursuing researches about Hauser, Chomsky and Fitch's hypotheses, some authors (Friederici et al, 2006) have shown that the treatment of simple sentences and structures based on concatenation (i.e. something looking like "***It rains and I take my umbrella***") is not associated to activations of the same neuronal zones of the human brain as the treatment of more complex sentences and structures implying embedded relatives and/or distance relations (i.e. something looking like "***If it rains then I take my umbrella***" or "***The boy the girl peter likes hates eats pizza***"). Brauer et al. (2010) have shown that the neuronal networks involved in the treatment of these long distance relations are not the same in children and in adults. This last observation can be interpreted as the necessity of a long maturation for the acquisition of the totality of the complex syntactic structures.

It is thus perfectly legitimate to wonder whether we can find a method which would favor the development of these complex neuronal structures in children.

7 New hypothesis : embedded structures presented via the pegboard can favor language acquisition.

We can consider our brain as a big Neural Network. According to Seidenberg (1997) our Language acquisition function is similar to a recursive Neural Network learning function. Such a function always has a recursive dimension. Taking into account the relations between language and recursion, as explained in the previous paragraph, it is tempting to wonder whether an approach making this dimension explicit could not foster language acquisition.

In order to try to explain the results obtained by Lefebvre et al. (2006), we now suggest that NVCD like approaches using recursive like problem-situations favor the acquisition and development of the verbal language. We have previously shown that such recursively oriented exercises can be introduced via an approach based on

Dynamical Mazes. We show here that exercises introducing nested structures can easily be created using an NVCD type approach based on the pegboard.

7.1 Exercises based on pegboard manipulations which imply some tail recursion

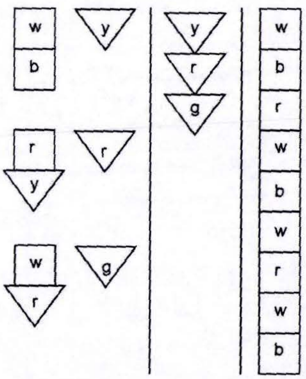

Figure 8 : non recursive call

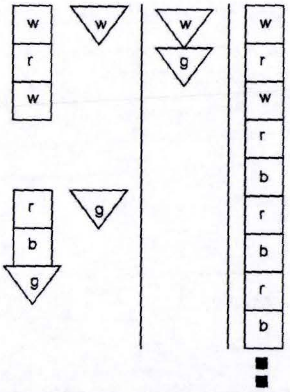

Figure 9 : endless "recursive" call

The exercise presented in figure 8 requires the subject to place first all the squares corresponding to the yellow triangle (i.e. the white square followed by the blue square), immediately followed by the squares corresponding to the red triangle (i.e. the red square followed by the squares **called** by the yellow triangle) and finally the squares contained in the definition of the green triangle or **called** by the triangle figuring in it. The result can be seen on the column to the right. The addition, at the beginning or at the end of the procedure, of "triangles" which are different from the "triangle" used to name the procedure will lead to a program containing tail recursive calls.

This type of "call" is simple to perform and to understand. It implies only a "simple return" to another procedure and not more than that : it does not correspond to embedded sequences but only to "calls". In the fields of language, these exercises have the same structure as simple sentences such as "The cat ate the mouse which was in the house", or, considering the case of two successive "calls" : "The cat ate the mouse which was in the house that Jack built". These exercises could help us train the subject to use "tail-recursion" but not complex structures containing nested clauses or distant relations.

The exercise presented in figure 9 contains two procedures : a simple one (named "white triangle") and a complex procedure (named "green triangle"). This last procedure is complex because it keeps **calling** itself indefinitely, thus creating the type of vicious circle we mentioned earlier : the execution can be started but will never stop.

The addition of a simple "triangle" identical to that used to name the procedure will lead to a program containing a pseudo recursive call which will never stop because the pegboard has no counter.

7.2 Exercises based on pegboard manipulations which imply actual nested sequences

The present discussions about the role of nested structures in language lead us to the conception of new exercises. The addition of "triangles" inside the definitions of the procedures enables the observer to use a modified version of the pegboard approach.

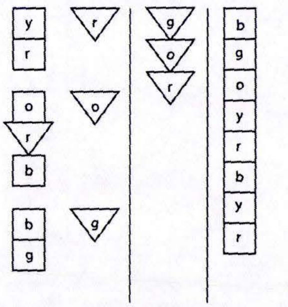

Figure 10 : a simple embedding

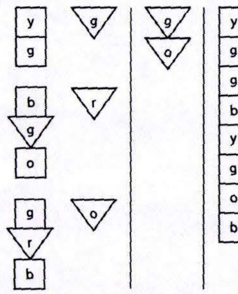

Figure 11 : a double embedding

The exercise shown in figure 10 is more complex than the previous ones. In this case, the subject must first place the squares corresponding to "green triangle" (i.e. the yellow square followed by the red square). He must then start treating "orange triangle" by placing the orange square, suspend the execution of this procedure and move one procedure up to place the content of "red triangle" (i.e. the yellow and red squares in that order) and then go back to "orange triangle" and place its last square. The subject can then move to the final procedure of the program and place the content of "red triangle".

The exercise presented in figure 11 is even more complex : in this case, after treating the "green triangle" procedure, one must move to the "orange triangle" procedure. This implies that the subject must place a green square, suspend its execution to start the execution of the "red triangle" procedure, suspend this one to execute the "green triangle" procedure once again and after this is done, go back to finish "red triangle" and then finally finish the execution of "orange triangle" We clearly have here nested structures of the same type as those we could find in the sentence "The boy the girl Peter likes hates eats pizza".

7.3 New hypothesis and new research trend

We formulate the hypothesis that the use of this type of exercises favors the acquisition of verbal language in young children (5 and 6 years old) as well as a faster neuronal development. We already know that 5 and 6 years old are able to perform easily all simple exercises, we also know that all 6 years old and a few 5 years old are able to perform very easily the "nested ones" (e.g. those shown in figures 10 and 11).

In order to test the first aspect of this hypothesis we will start a new research. Subjects will be first tested using existing tests enabling the researcher to evaluate the richness and the complexity of their language (pre-test). They will then start solving a sequence of exercises leading to those shown in figures 10 and 11. Finally, they will undergo the same tests as those used for the pre-test : theses tests will serve as first post-test. A second phase of post-test will occur one year later since previous experiments have shown the importance of such a delay for the maturation process. These "experimental" subjects will be compared to a control group.

Later, a similar treatment will be used but the pre- and post-test will be completed by fMRI observations in order to observe the active zones during verbal tasks and the paths followed in the brain by the information.

8 Conclusion

We presented here a non verbal approach designed to observe and favor children's cognitive development. The results of several researches were presented. They all tend to show that these non verbal approaches foster language development in normal and handicapped subjects, and favor language re-acquisition in some patients with cerebral focalized lesions. The question "why does it have this influence ?" was raised and an experiment was described showing that this type of approach has an influence on the brain. In order to understand why it is like that, we first examined the role of recursion in language and then observed that the recursive structures embedded in some NVCD type exercises might play a major role in the NVCD influence on the brain. In order to test this new hypothesis we presented here new exercises clearly making nested structures explicit in a non verbal way. We know that these exercises are accessible to some 5 years old and to all 6 years old. We have thus started a new research based on the use of these exercises.

The questions we want to answer are the following ones : "is the language acquired after an NVCD type training with such exercises richer and more complex than the verbal language usually used by 5 and 6 years old ?" and also, after a deep analysis of these subjects verbal productions, can we say that "their language, after the use of an NVCD type approach based on nested structures, became more adult-like ?"

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