RELEVANCE OF TYPICALLY LOGICO-MATHEMATICAL FORMALISMS FOR RESEARCH IN PSYCHOLOGY

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A logician trying to work his way through a paper written by a cognitive psychologist will almost certainly wonder: "What is the nature of the reasonings the author is writing about?". This leads to a deeper question: "What is the actual nature of natural logic?. In fact most psychologists, doing research in the field of cognition, tend to describe how this logic "behaves" with respect to actual problems; but they do not try to discover what this logic actually *is*. Is it a logic based on an axiom system or is it a logic of the kind described by GENTZEN? Moreover, if this logic is based on an axiom system, should one assume that this axiom system is present at birth and becomes of use only when the subject matures, or is it a super-system which is the result of a long construction? In this last case, the resulting system could be the sum of small systems encountered during the subject's childhood and put together in order to create a beautiful mosaïque. These questions are complex and their solution is difficult, but a logician can dream to offer a solution. He can even try to materialize his dream!

The aim of this paper is to describe the nature of the problems encountered by cognitive psychologists, to offer a technique to study them from a logician's point of view and to envisage the consequence of the choice of such a technique with respect to the problem of the actual nature of natural logic.

Problems encountered by cognitive psychologists

Cognitive psychologists study the way in which people in general, and more specifically children, solve problems. In order to do so many researchers use the clinical method described by PIAGET. They communicate with the child by means of the classical verbal language and ask questions such as: "What do you think it is?", or "Why did you do this?". Nevertheless, the verbal language they use is not necessarily the same as

the one used by their own subjects. Inevitably, this verbal language is full of ambiguïties and is even based on non obvious logical structures. In fact, to avoid the communication gap between researcher's and child's language, both languages should be based on the same logical structures. This implies that the child should have a perfect mastery of adult logic; but according to these same researches this is not the case and this is why they keep studying the development of natural logic in the child. The technique of verbal interviews seems thus rather inappropriate for the study of cognitive development since verbal communications do not seem to be adequate.

The basic problem is due to the fact that these researchers insist on *communicating* with the child. There lies the cause of all their problems. We claim that they do not need to communicate: what they really need is a good *representation* of what is happening in the subject's mind while this subject is solving problems.

Other researchers, such as BINET, SIMON, ZAZZO and others, claim that they can obtain some kind of representation by means of standardized tests. They think that these devices will enable them to get a better definition of their frame of work and will thus enable them to easily compare the subjects. They probably gain in clarity and their observations are probably more easily interpretable; unluckily they loose a great deal of the flexibility offered by the verbal language. Moreover, the restrictions imposed by the use of standardized tests make it impossible to obtain informations which are as rich as those obtained by means of the clinical method: the test-users do not get a representation of what *is happening* in the subject's mind: they only get an evaluation, a static picture. This will certainly not help us to know, first how natural logic functions, and then what its actual nature is.

In order to combine the rigour of observations made by means of standardized tests with the richness of those obtained thanks to the clinical method, it appeared useful to use a clinical approach restricted to a well defined and "logically" organized universe. PAPERT tried to use the computer as medium and controler of some kind of representation of the child's universe. His technique bears fruitful results and gives relevant information about the children's thinking behaviours. Nevertheless, this technique is based on interactions with the computer and these interactions must occur through a key-board (and this is a first hinder for young children) and through verbal messages produced in a simplified but ver-

bal language by the child and the computer. This brings us back to the first kind of problems: how can one use any form of verbal language to study the development of natural logic, if a mastery of natural logic is required to have a good access to this verbal language which in turns is supposed to be the best model of natural logic? The situation seems hopeless and there seems to be no way to get out of this vicious circle.

A logician's proposal

BRUNER noticed that children solve the problem we described above and break this vicous circle by playing with objects, they thus discover the regularities of their environment and build the bases of the logic they need to acquire the first elements of a verbal language. This verbal language can then be used as representation medium.

These observations lead us to try to use more structured material than everyday's objects: it becomes then possible to observe how children react to the structure present in the technical constraints of a device. This enables the observer to say what part of his logic is assimilated by young children (his subjects). In order to do so, the observer should let the children manipulate devices which are concrete representations of formal systems: the objects used are the symbols and the technical constraints present in the material represent the deduction rules which will, or will not, be used by children. Such concrete manipulations enable the observer to confront the child with a logical problem in order to obtain a representation of what happens in his mind. Our approach is based on the use of collections of objects which can be used as *"a concrete representation of a formal system which is sufficient to accomplish some reasonings"*. We call such devices "Non-Verbal Communication Devices" (NVCD).

This simple definition has numerous consequences which are all advantageous for the observer:

- an NVCD is made of *concrete objects* (DIENES' Attribute blocks, Lego bricks, ...), it can thus be used in a nearly non-verbal way to introduce problems to a child and observe how he solves them: this enables the observer to avoid the problem of verbal communication used as a representation device!
- this device must also *represent* a formal system, it is thus made of many elements which are independent of any cognitive background: they

are non-ambiguous and their use makes it possible to avoid the unpleasant effects of "uncontrolled prc-knowledge".
- the device is a *concrete* representation of a formal system, it is thus made of numerous little elements which can be grouped in a small number of categories; these little elements (i.e. "symbols") are easy to handle and must be used one after the other: the problem must be solved in a stepwise fashion.
- such a device represents a formal system which is sufficient to accomplish *reasonings*, the elements which constitute the device can thus be put together in many different ways.
- such a device is a *concrete representation* of a formal system sufficient to perform reasonings, it must thus carry *one way or the other* a syntax which, at the concrete level, is represented by technical constraints.
- finally, such a device favours the *manipulation* of numerous small elements, which makes it attractive.

Genarally speaking one considers that any set of objects can be used as an NVCD, provided that it is furnished with technical constraints; these constraints make certain actions possible and others impossible, and this, in turn suggests a logical structure which enables the observer to notice how reasonings are elaborated: indeed, the solutions produced by means of such a material are built in a stepwise fashion since the device is made of numerous little elements.

Consequences of the choice of such a technique

The use of NVCDs makes the observation of reasonings in normal children easier. Moreover, such observations by-pass classical problems due to the use of the usual verbal language as a medium for communicating representations, and to the permanent recourse (voluntary or not) to the subject's cognitive background. In fact this technique makes it possible to observe in an objective way representations (in this case: manipulations of abstract objects) of the subject's problem-solving strategies, without having to communicate anything about them in an ambiguous way.

It is even more interesting to use this technique with handicapped children, since the other methods always fail because of the huge com-

munication gap and of the lack of cognitive background common to both subject and observer. Aphasic children, mentally retarded persons and socio-culturally deprived children have been observed by means of NVCDs. In all cases the observations show that logical competences are present in them, although they do not master the classical performances associated to them: "they can do it but they cannot say it". This had not been noticed by means of other techniques, and it could not have been noticed since the basic assumption of the researchers was the absence of such problem-solving habilities. Observations of subjects whose logic – according to all classical standards – is defective, give even more relevant information concerning the way "THE" natural logic works, than usual observations of well-performing normal children: as usually one counter-example enriches the observer more than the examples. One must show the absence of all possible counter-examples to prove a universal statement, and not show many examples; also, one single counter-example suffices to show that a universal statement is false!

It is important to remind here the reader that the purpose of this paper is not the description of the functioning of the natural logic, but the presentation of a tool which appears very useful to study it.

As far as the nature of this logic is concerned, the logician, who is lost and dreaming in the middle of the field of psychology, has no evidence to offer. He can only formulate an hypothesis based on observations made with NVCDs. In fact, an NVCD is a useful observation tool, but this observation is not neutral. The device bears a logical structure and children using it seem to acquire some elements of the hidden structure: it has been shown that 6-year olds learn very significantly better ($p=.005$) to read after using an NVCD which induced them to make and test hypotheses about "what is going to happen next", it seems that these children learn to structure their expectations concerning "the next word". In other domains transfers of structural nature have been observed. These transfers do not seem to be associated to either the age of the subject, or to the nature of the tasks: the nature of the transfers is associated to the nature of the logical structure hidden in the NVCD used. Comparable transfers were observed for children of different ages, provided with similar NVCDs. The use of these devices seems thus to favour the cognitive development and we have strong experimental reasons to assume that this occurs as follows: at first, the subject learns to distinguish the relevant and the irrelevant elements of the material; he then starts to connect locally

some of these relevant elements; a shift in the level of relevance leads him very quickly to consider the blocks he has created as the new relevant elements and he starts to connect these blocks; further shifts in the level of relevance will eventually lead the subject to connect all the relevant elements, to discover the global structure associated to the material, and finally to transfer the newly acquired structure to other domains.

This process seems to occur similarily at different ages (for a given NVCD) and for different NVCDs, thus for different structures, at a given age. As BRUNER did NOT say, it looks as if "everything could be taught at any age". The evidence obtained by means of observations made with NVCDs also show that different children use solving-problem strategies which are *different in nature* although they are *functionally* equivalent. We thus do not believe in the existence of a general inborn axiom system which is suddenly activated when the child is mature enough, nor do we believe that such a general and unique system could exist and become slowly more and more "active" as the child gets older. We much prefer to think in terms of a natural logic which would differ from individual to individual: each person seems to build his *own* natural logic by grasping small structures on the way and by integrating them in order to create a big structure. This means that the natural logic, which – *we insist* – must be different for each person, should be a mosaïque of small axiom systems, or a mosaïque of deduction rules. In fact, *for all practical purposes*, as far as cognitive psychologists are concerned, tiny axiom systems or very small collections of deduction rules are equivalent. It is only the logician who can claim that there is a difference: the difference lies actually in the logician's mind, in the way he looks at a BIG structure in order to describe it convincingly. The observations gained by using NVCDs tend to show that these BIG descriptions are neither relevant for those who wonder what the nature of natural logic actually is, nor are they relevant for those whose aim is to describe how such a natural logic functions. An individual's natural logic will be his own construction, it will probably differ from all the other existing natural logics; furthermore, it will be a mosaïque of small structures which this individual has met somewhere on his way through life, and which were small enough to be assimilated and to become integrated parts of the big structure this individual, unknowingly, has built. This big structure is probably not pure: some "substructures" are probably small axiom systems while others are micro-collections of deduction rules, and the ratio between the two kinds

of substructures varies most probably from individual to individual. For all these reasons we strongly believe that the nature of an individual's natural logic depends on his background, his environment, the things he could see, touch, manipulate, ...

Conclusion

These remarks might help us to understand why NVCDs appear useful to make further studies concerning the functioning and the development of logic in children: NVCDs are independent of the cognitive background, they can be seen, and touched, and manipulated; their use implies no prerequisites. It seems thus that they can be fruitfully used with many people: they can be used in a case study with one single individual, they can be used to examine the logical structures some people having a similar background actually share. NVCDs can also give informations concerning people coming from different backgrounds because the NVCDs are attached to nothing: they are simply concretisations of formal systems.NVCDs are made of bits and pieces which can be assembled and organized: we believe that, in a Brunerian framework, this corresponds to what is actually needed to activate the basic human *capacity* of creating a natural logic.

The researcher must be aware that all his observations will lead to divergent conclusions since the thing which is observed – natural logic – is not really ONE SINGLE thing: it must be an impure mosaïque of all kinds of small structures gathered by each individual during his previous experiences. This also means that, by essence, the observation can never be finished, since a natural logic is never completely built but keeps growing.

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