THE STUDY OF COMPETENCE
IN COGNITIVE PSYCHOLOGY [1]

JACQUES MEHLER *Centre National de la Recherche Scientifique, France*
THOMAS G. BEVER *Rockefeller University, New York, USA*

Les auteurs passent en revue certaines tendances contemporaines concernant l'étude des processus cognitifs et ils mettent l'accent sur quelques-uns des problèmes non résolus par ces théories. Ils centrent leurs recherches sur ce qui est naturel dans les processus cognitifs à certains niveaux de comportement par opposition à ce qui serait possible à tous les niveaux. Cette approche conduit à diviser l'étude des processus cognitifs en trois parties : il faut d'abord déterminer les capacités initiales des jeunes enfants, puis définir les états stables atteints par les adultes et enfin trouver une théorie de l'apprentissage qui explique le passage des unes aux autres. Les recherches préliminaires ont mis en évidence plusieurs principes déjà connus en psychologie mais dont on ne s'était jusqu'ici pas méthodiquement servi pour l'étude des processus cognitifs. Premièrement, l'échec à une tâche cognitive ne signifie pas nécessairement que cette tâche soit impossible à effectuer sous d'autres formes. C'est donc dire qu'on ne peut conclure à une absence des règles nécessaires pour l'exécution. Deuxièmement, le développement n'est pas à sens unique; on trouve non seulement des plateaux dans le développement des capacités sous-jacentes à des comportements spécifiques, mais aussi des baisses temporaires de performance dues à la dynamique du développement cognitif. Finalement, en linguistique comme en cognition, les auteurs n'ont trouvé aucune raison qui puisse les amener à supposer qu'une théorie formelle et descriptive soit une représentation fidèle des opérations psychologiques qui conduisent aux performances des adultes.

It is our view that cognitive theory must present an axiomatic formulation of the processes which are involved in creative behavior. This definition of the goal of cognitive psychology is analogous to the goal of generative linguistic theories, *i.e.*, Chomsky (1965). Current linguistic models have a finite number of rules which generate all the sentences that are intuitively natural to a particular language for the language user and no sentences that are not natural to that language. The primary methodological contribution for cognitive psychology of these linguistic investigations is the distinction between what a person can learn to do and what he is disposed to do naturally within a particular cognitive domain. For example, a speaker of English *can* utter both " Dog is a nice Sam ", and " Sam is a nice dog ", but only the second of these possible utterances is acceptable as a grammatical instance of English, and is a sentence which must be described in a linguistic theory of English. Analogously, we limit the data relevant for other cognitive skills in terms of natural predispositions rather than in terms of ultimate

capabilities. For example, consider the interpretation of " *if* it is sunny tomorrow, *then* we'll go on a picnic "; such a sentence *can* be interpreted to mean both (a) that if it is not sunny we will also go on a picnic and (b) that we will go on a picnic only if it is sunny. Only the second interpretation is natural and immediate, and as such must be included as a fact relevant for a theory of the natural patterns of the psychology of inference.

Each kind of cognitive phenomenon defined in terms of natural predispositions may be studied by examination of three components : description of the natural predispositions of adults who have reached a *stable state* ; a characterization of the minimum *initial state* that infants have in their basic functioning; a *dynamic theory of acquisition* which, when coupled with maturational and other processes, enumerates the stage, or transitions, of cognitive development.

THE INITIAL STATE

For centuries various versions of empiricism have dominated psychological theory; the main theme of these views is that there is little more at birth than a hypothetical blank brain. The modern form of this position was developed by Locke and has since been defended vigorously for the past half century. However, concerted attacks by modern rationalists and experimental psychologists have weakened the contemporary behaviorist position. For example, Chomsky (1965) has shown that there must be an internal structure that guides the learning processes if learning is to take place at all. Katz (1966) has argued that the environment is too impoverished for empirical theories to account for the structures that appear in language (see Mehler (1968) for a review of these arguments).

The moral of such arguments is the same : random environmental events cannot themselves structure an inherently random organization. Further, if the internal organization is completely random, no abstract structural relations could ever be perceived (*e.g.*, time, grammatical functions, three-dimensions). Most important, it is reasonable to believe that some behavioral structures are genetically encoded. For example, physiologists argue that there must be universal laws for the functioning of the nervous system (still poorly understood). Therefore it is an irrational scientific strategy to deny this and base our theorizing only on the study of what is learned and how it is learned. It may be suggested that we are arguing against a " straw man ", since allegedly no psychologist maintains such a strong form of empiricism. However, cursory examination of the literature (*e.g.*, Staats, 1966; Gagné, 1968) shows that radical behaviorism finds many serious modern proponents. Also, while many other cognitive and developmental psychologists pay lip-service to the " obvious " presence of at least some innate structures, they do not devote theoretical or experimental attention to exploring the exact nature of such structures or their interaction with experience.

However, some psychologists have given attention to defining the structure of the initial state. Recently a number of experimental results have shown that one can no longer assume a blithe absence of structural and operational capacities in newborn infants. For instance, Bower (1966) has demonstrated that

babies have a number of sophisticated heuristics to deal with their environment from the earliest ages at which they can be tested. Perceptual constancies, *e.g.* shape, are present earlier than the simpler physical parameters that were claimed to underlie the constancies (*e.g.*, apparent distance and orientation). He also concludes that the " good forms ", in the Gestalt sense, are already " good " when babies perceive them for the first time. This research suggests that children draw general parameters from innate perceptual heuristics.

As another example of this sort, ethologists have found that while baby ducks do learn the concept of their own species from experience, the progress of the learning is not in small increments nor over a protracted period of species-specific stimuli and reinforcement. Ducks are imprinted to the first moving organism they see a certain time after birth : it is the object to which they are first imprinted that determines the species towards which they later demonstrate sexual responses. Here too we see that a particular innate structure underlies a general pattern, recognition of " mother " and a " species-generalization ", which an empiricist account would ascribe to accumulated experience and reinforcement (the continual presence of a " mother " and other members of the " species ").

The general empiricist pattern of research on children has been to determine what operations a child cannot perform at a given age and to investigate later ages at which the child can perform those operations. Typically, a progressive study (in age) is carried out until the child shows that he is capable of the behavior in question. The experimenter concludes that the given operation appears, or is first constructed, at the older age and further research appears unnecessary. This type of developmental study must be avoided for both theoretical and empirical reasons.

Although we may draw conclusions about abilities from the child's successful performance, we cannot infer the child's underlying incompetence from his failure to perform. Failure to perform can be due to the child's being asleep, to his indifference to the task, to his trouble in understanding verbal or implicit instructions or to limitations in such expressive functions as memory and attention. If the child fails to perform on a task, we face the same dilemma as the statistician who tries to prove the null hypothesis. If a psychologist finds that a given behavior is not exhibited by children below a certain age, then he must explore the reasons through further experimentation and studies of both younger and older children, rather than postulating a " basic incapacity " that " disappears " at a later age. Accordingly, our own research strategy has been to ascertain the initial state of the capabilities of children and then to study the stages the children go through in attaining the stable state; in our initial studies we have found that an older age can be associated with *poorer* performance than that at a younger age (see below).

THE STABLE STATE

The determination of general cognitive capacities is analogous to the isolation of the competence of the language user. In language, the stable state is defined in terms of a set of clear intuitions about those sequences that are well-formed sentences. That is, without any linguistic training every speaker knows whether

a sequence is part of the language or not. Analogous intuitions are much less clear in the case of other cognitive capacities. Although nobody has yet described the internal structure of the intuitions that are relevant to an overall theory of cognitive operations, some writers are convinced that there is a possibility of finding such a form. For example, Gardner (1968) believes that this might appear from examination of the universal logical laws that underlie the different number systems. " In fact, every now and then a cultural anthropologist, over-eager to drag science and mathematics into the folkways, argues that because different tribes have calculated with different number systems mathematical laws are entirely cultural, like traffic regulations and baseball rules. He forgets that different base systems for the natural numbers are no more than different ways of symbolizing and talking about the *same* numbers, and are subject to the same arithmetical laws regardless of whether the number manipulator is a Harvard mathematician or an aborigine adding on his fingers. " (p. 229).

Gardner clearly believes that some putative formal rules of mathematics must underlie our psychological conception of the number system just because the rules are formally universal. This would be due to the innate (or learned) presence of the logically analyzed operations : existence, identity, addition, subtraction, transitivity and associativity. It is not at all obvious, however, that the structures which underlie basic mathematical and logical structure also directly underlie actual psychological processes. The relation between formal and actual logical structures is a matter for empirical research, not *a priori* assumptions.

For example, studies of the development of thought have demonstrated differences in the manner in which children handle simple logical operations at different ages. In a recent study, Maury (1968) has shown that children understand the negative complement (De Morgan's laws of negation of logical statements) in a manner that changes with age. Younger children handle " (not (a and b)) " by performing as if it were the expression " (not a and not b) ". Finally, by age ten, children generally understand the correct implications of the negative expression of a conjunction. Other experiments have shown that there is an analogous development in the manner in which children handle cartesian products, partitions and other such logically described functions (Rogalski, 1968; Vergnaud, 1968).

Such developmental changes in the interpretation of logical relations emphasize the general problem about the role of formal logic in thinking. The fact that we use numbers and logical arguments and the fact that we can learn to understand the formal structures constructed by logicians and mathema-ticians does not prove that they are the psychologically primitive operations. (Similarly, the fact that we can learn to say random word strings does not bear on the natural structure of sentences in a language). In fact, it is futile to show that universal mathematical and logical structures can be recruited to describe instances of actual behavior : such universal formal structures can be used to describe anything we can observe — of what conceivable interest is it to show that a mechanism which can describe anything can " also " describe particular aspects of behavior ? A more pertinent goal for formal study of cognition is to find the universal structures that are just powerful enough to describe natural behavior. Thus, in contrast to Gardner's view, it may be the case that we must learn the formal structural analysis of numbers and logical inferences as a special

skill. That is, basic psychological structures are combined and articulated in actual cognition to simulate the formally universal mathematical and logical structures, rather than the reverse.

Consider the use of logical disjunction by adults : " a or b " is ordinarily interpreted as exclusive disjunction (that is, " either a or b, but not both ", *e.g.*, " if it is sunny we will go to the beach or on a picnic " is not intended to be a statement of the intention to " have a picnic at the beach "; although such conjunction of events might not falsify the disjunction, it is certainly not expected from the form of the statement). Although we can also interpret disjunction conjunctively, as shown in psychological concept-formation experiments or special uses of language, the natural or " primary " interpretation of disjunction is exclusive. Yet universal logical systems which maintain associativity must use inclusive rather than exclusive disjunction if disjunction is to be a two-place operation. This is one example of the potential conflicts between formal logic and actual psychological operations. Of course, such conflicts may be due to failures of performance of the actual formal logical structures, due to an incorrect analysis of the universal formal structures, or due to essential differences between primitive logical and psychological structures. Which ever of these alternatives is true must be studied by empirical research into particular domains of cognitive skill.

Unfortunately, the determination of the intuitions and facts pertinent to a particular stable state of cognition is quite difficult. The difficulty is in part due to the fact that the behavioral basis for a particular set of " naturalness " intuitions is never clear. Consider again the case of language. There is allegedly a stable state that is attained in language learning, namely, the " knowledge of the language " by a native speaker. Nevertheless, the speech patterns of individual adults differ from that of 2-year-olds and of 4-year-olds in many respects. Does this mean that the underlying processes of language in different adults and in children have nothing in common ? Or is it possible that at least some basic components are the same and that the important changes in performance are due to ancillary processes of language use ? We know that some rules are hidden in particular human performances because of channel limitations or peculiarities. One hypothesis that has been little explored in the study of cognition is that expressive limitations are responsible for the performance differences rather than internal structural differences. For example, the memory span is assumed merely to expand with age. There is little reference to the possibility that the changes that take place are in the form of encoding stimuli or in the internal nature of the memory processes themselves. The same is true for the usual conjectures about the development of attentional processes. However, there is reason to suppose that much of the development of what we have been calling the expressive performance processes is both quantitative and qualitative. There-fore it is too simplistic to claim that the development of performance capacities and the performance differences among adult individuals are merely quantitative.

How can we decide if a developmental change or behavioral difference among adults is really due to a difference in a structural rule, to a difference in the form of the expressive processes or a difference in their quantitative capacity ? One kind of data which can resolve such dilemmas is the developmental changes of the different processes that are involved in cognitive tasks. For

instance, a particular structure might be implicit both to the understanding of a passive sentence and to the solution of a particular logical problem. Nevertheless, the passive sentence might be understood at an age younger than that at which the corresponding logical problem can be solved. In such cases it may be reasonable to conclude that the structure is present as part of the cognitive capacity of the child but that it is not expressible through the particular performance processes involved in solving logical problems at that age.

The main assumption of such a view of cognition is that a structural rule may be always the same regardless of the channel in which it is expressed. A rule serves many purposes and as a computational device it can be used in many different applications. There is no *a priori* reason to assume that a particular basic structure underlying apparently different behaviors is represented by different internal mechanisms; for instance, we do not need to postulate one kind of structure for the solution of logical problems and another for the perception of linguistic stimuli with formally identical internal structure. It is certainly conceivable that there are separate rules for each kind of capacity. But until such a demonstration is forthcoming there is no reason not to adhere to the principle that actual cognitive structures must be studied independently of their particular expression.

Thus one way to study structural competence is to investigate when different types of cognitive rules first appear independent of the channel in which they are expressed. We re-emphasize that the kind of rule to search for in each cognitive domain is not necessarily related to formal universal mathematical descriptive structures (which by definition can describe anything); rather the different kinds of behavior must be described in terms of those structures that are psychologically natural. Thus, a strategy of scientific investigation is still necessary to isolate the natural psychological structures in different domains of adult behavior, (*e.g.*, language or patterns of logical inference) before searching for their common psychological and ontogenetic basis.

THE PROCESS OF ACQUISITION

Ultimately we must establish which structures are functionally innate and which are a consequence of the interaction of general computational capacities with specific experiences. It has generally been assumed that if a capacity is not utilized by a child at a given age, then the child could not have exhibited that capacity at an earlier age. This common sense assumption is in fact untrue. For example, the child's memory capacity at age four is three items but it is larger for certain kinds of stimuli at age three. Our recent experiments (Mehler and Bever, 1967; Bever, Mehler and Valian, 1968) have shown that 2-year-old children solve problems that older children are not able to handle. Children show decreases of this sort with increasing age on problems in language, thought, and other cognitive tasks. Thus the growth of cognition departs from the linear accumulative development that earlier assumptions had led us to expect.

We interpret such oscillations in performance as the result of dynamic alternations between structural and inductive modes of processing : the 2-year-old child starts out with fundamental cognitive structures, but his ability to combine

and apply these structures is constrained by the behavioral limits on such expressive capacities as attention and memory. The child then actively creates the inductive strategies to expand the application of his basic capacities and circumvent the infantile limits on his expressive capacities. (It is these inductive strategies that lead to poorer performance in the older child on those problems in which superficial inductions fail). This kind of interpretation of development is in contrast with one which assumes an initial lack of cognitive structures and a passive accumulation of them with age and experience.

Unless the whole dynamic range of cognitive life is included, it is unclear how useful a cognitive theory could be. But most current theories of learning have a particular learning mechanism in mind and consequently the data with which each theory can deal are partial. A theory of learning must describe more than a particular cognitive stage or series of stages : it must also describe the active mechanisms by which the stable states are derived from the initial states[2]. It is important to develop theories of structural and personal motivation for cognitive change. For example, we must account for certain critical stages in the development of thought that are independent of and resistant to outside experience. Consider the changes that Piaget (1956) has described in his studies of the child's notions of numerical quantity. " Conservation " eventually appears and little can be done to accelerate or prevent that development. But why does the child who does not conserve suddenly develop conservation ? There are some descriptions that give more details about this fact, but there is no view that can explain why the child switches from one manner of processing to the next. We have argued that this particular development is a change from local perceptual heuristics to analogical heuristics although in itself even this account is not explanatory. Thus it is necessary to devise a dynamic learning theory with principles that account for the changes that take place and describe how internal and external experiences motivate the changes. Such an internally motivated explanatory theory of cognitive progressions is distinct from a taxonomic description of change in terms of a homeostatic process of equilibration and disequilibration (*cf*. Piaget, 1968). We agree that such homeostasis occurs in every active aspect of living and artificial systems. But the pervasiveness of such a principle is an observed fact about systems that interact and change, not an explanatory theory of the changes themselves.

CONCLUSION

We have outlined our current views about the study of cognition and some of the unsolved problems that these views define. In our research we focus on what is cognitively natural at a particular level of behavior as opposed to what is cognitively possible at all levels of behavior. This approach divides the study of each aspect of cognition into three parts : isolation of initial capacities in young

---

[2] We define a learning theory as a function which maps the initial state onto the stable state. Of course, such a function cannot be considered as being neutral in respect to the theoretical terms in which it is expressed. It is our belief that its correct expression is derived from the understanding of the universals encountered in the study of the initial state.

children; isolation of adult capacities; specification of a learning theory which explains the derivation of the latter from the former. Our preliminary studies of these problems have emphasized several principles which have been recognized at one time or another within psychology but not combined in the treatment of cognition. First, the failure to perform on a particular cognitive task may not signify a failure to comprehend the structure of the task, nor does it signify an inability to perform on some other superficially different task with the same internal structure. Second, development is not unidirectional : not only are there *plateaux* in the development of specific behavioral capacities but the dynamics of cognitive development can lead to temporary decreases in certain skills. Finally, the basic adult cognitive structures may not include the most powerful laws of mathematics and logic, but rather consist of particular basic psychological operations.

REFERENCES

BEVER, T.G., MEHLER, J. & VALIAN, J. Linguistic capacity of very young children. *Child Development*, 1968 (in press).

BOWER, T.G. The visual world of infants. *Scientific American*, 1966, **215**, 80-97.

CHOMSKY, N.A. *Aspects of the theory of syntax*. Cambridge, Mass. : MIT Press, 1965.

GAGNE, R.M. Contributions of learning to human development. *Psychological Review*, 1968, **75**, 177-191.

GARDNER, M. Mathematical games. *Scientific American*, 1968, **219**, 218-230.

KATZ, J.J. *The philosophy of language*. New York : Harper Row, 1966.

MAURY, J. Etude expérimentale des opérations : Réunion, intersection et complémentation. (In press).

MEHLER, J. La théorie innéiste est-elle devenue adulte ? *Psychologie française*, 1968 (sous presse).

MEHLER, J. & BEVER, T.G. Cognitive capacity of very young children. *Science*, 1967, **158**, 141-142.

MEHLER, J. & BEVER, T.G. Discovering what the two-year-old child can do. *Science*, November 1968.

PIAGET, J. Quantification, conservation and nativism. *Science*, 1968 (in press).

PIAGET, J. & SZEMINSKA, A. *La genèse du nombre chez l'enfant*. Neuchâtel : Delachaux & Niestlé, 1941.

ROGALSKI, J. Etude du produit cartésien. (A paraître).

STAATS, A.W. An integrated-functional approach to complex human behavior. In B. Kleinmuntz (Ed.), *Problem solving. Method, theory and research*. New York : Wiley & Sons, 1966.

VERGNAUD, G. La réponse instrumentale comme solution des problèmes. Thèse de doctorat, Paris, 1968.