PREHISTORY AND COGNITIVE DEVELOPMENT

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The perspective of genetic epistemology

This chapter deals with cognitive development in prehistory from the perspective of Jean Piaget’s genetic epistemology, applying concepts such as the concept of sensory-motor intelligence, preoperational thought, and operational thought to the early development of human intelligence. Following some introductory remarks on the application of genetic epistemology in cross-cultural and historic comparisons, the origin of man and the Neolithic and the Urban Revolution will be examined. Finally, the chapter will conclude with a review of genetic epistemology and prehistory.

Introductory remarks

Jean Piaget developed his conception of genetic epistemology and the categories for describing genetic stages when he became aware of fundamental changes in the thought processes of the developing child. He identified invariant psychological functions such as assimilation, accomodation, equilibration, and reflective abstraction, which generate a discontinuous universal sequence of subsequent stages of cognition, each of which gives rise to specific cognitive achievements (see, for instance, Piaget 1970, chap. 3).

Sensory-motor intelligence is the level of a “practical intelligence“ based on a close relationship between action and cognition. At this level of cognition, sensory data are assimilated to generalized schemes of coordinated, repeatable actions, which can function at the level below mental representation and conscious thought. These schemes of action or “practical concepts“ are generalized, differentiated and integrated in the course of sensory-motor activities by accomodation to the growing amount of sensory-motor experience.

At the level of preoperational thought sensory-motor intelligence is supplemented by the symbolic function, i.e. the ability to represent something by symbols and eventually to distinguish objects from the “preconcepts“ which correspond to meanings of the symbols at the level of cognition. Practical intelligence is internalized, generating mental imagery which is the precondition for language acquistion and for abilities such as drawing, painting and modelling.

The developmental stage of operational thought emerges when internalized actions turn into reversible mental operations, and abstract entities such as quantity, time and space are constructed by reflective abstraction from such systems of mental operations. They constitute the structures of logical and mathematical thinking which are usually assumed to be human cognitive universals.

The extent to which we can reasonably apply psychological categories that describe stages in ontogenesis to phenomena in prehistory will not be discussed here in detail. Piaget himself, at least, believed that the basic concepts of his genetic epistemology not only represented psychological phenomena but also that they were epistemological categories covering cultural and historical aspects of cognitive processes.

One specific theoretical problem in applying these categories to prehistoric and historic observations, however, must be briefly discussed. Piaget claims that the ontogenetical stages of cognitive development are universal. He claims that differences in the environment have no effect on the sequence in which these stages occur or on the logico-mathematical structures of thinking that are the final cognitive outcome. Such a theory seems unsuitable for explaining cultural or historical differences in cognition because it can account for these differences only by assuming that they are due to different rates of progress through ontogenetical stages.

This is, indeed, how genetic epistemology is usually applied to cultural differences. It is generally accepted that ontogenesis reaches its final stage of formal operational thinking only if the environment fulfills certain requirements. Unfortunately, experts disagree about the degree to which development may be delayed. Gustav Jahoda (Jahoda, 1980, p. 116), for instance, writes in a review article on the Piagetian approach to cross-cultural psychology:

„It can be stated quite categorically that no society could function at the preoperational stage, and to suggest that a majority of any people are at that level is nonsense almost by definition.“

But this is precisely what Piaget and others——recently, for instance, Hallpike (Hallpike, 1979)——assumed and what will also be assumed in the following. Piaget elaborated this assumption in his monumental Introduction à l'épistémologie génétique(Piaget, 1950)——which has unfortunately never been translated into English. Influenced by the discussions in the 1920’s about the interpretation of ethnological findings as evidence for culturally specific modes of thinking and, in particular, by Lévy-Bruhl’s ideas about primitive mentality (Lévy-Bruhl 1923), he introduced the theory that among primitive people ontogenetic development reaches only the level of preoperative thinking. He argued that there may well exist a seemingly great discrepancy between, on the one hand, the practical intelligence of such people based on mental imagery, intuitive thinking and symbolic representation and their ability to build higher-level concepts by reflective abstractions and deductive thinking on the other hand (Piaget, 1950, Vol. 3, 260-262).

In a similar way Piaget envisaged the application of his categories to the study of the devopment of cognition in prehistory. In his Woodbridge Lectures on genetic epistemology he argued (Piaget, 1970, 13):

„The fundamental hypothesis of genetic epistemology is that there is a parallelism between the progress made in the logical and rational organization of knowledge and the corresponding formative psychological processes. Well, now, if that is our hypothesis, what will be our field of study? Of course the most fruitful, most obvious field of study would be reconstituting human history—

the history of human thinking in prehistoric man. Unfortunately, we are not very well informed about the psychology of Neanderthal man (...). Since this field of biogenesis is not available to us, we shall do as biologists do and turn to ontogenesis."

Methodological difficulties

Our information about the psychology of humans in prehistory is, in fact, extremely limited. The common psychological methods of data collection are irrelevant in archaeological research. Psychologists usually interact with their subjects of investigation by means of interrogations, experiments and tests and they scrutinize their observations in order to reconstruct the mental processes involved in the observed activities. In the case of prehistoric humans, however, only some extremely durable material remains are transmitted to the modern scientist which can lead to some conclusions concerning the activities that might have been necessary to produce or to use the transmitted artifacts.

Moreover, there is a difficulty inherent in genetic epistemology which makes the situation even worse. According to genetic epistemology, the basic structures of cognition reflect the coordination of actions, not the actions themselves. It is, therefore, not possible to directly infer from an observed behavior the level of cognition involved. The same action, say, walking from one location to the other, may indicate completely different levels of cognition. Such an action may be the immediate outcome of sensory-motor activities. It may result from following a verbal description of those landmarks marking the way; it may have been planned in advance by reading a map; or, it may be part of the systematic exploration of an unknown area by a highly competent individual. If there is no possibility to communicate with the subject investigated in order to find out more about the context of the observed behavior, the only way to infer the level of cognition is to observe how the total actions of this individual are coordinated and how they are related to other activities in his social environment.

The gap between what we know about human activities in prehistory and what we need to know in order to reconstruct the development of cognition cannot be bridged here. The aim of this chapter is limited to examining the information provided by palaeoanthropology and archaeology about the development of forms and functions of human artifacts and the human behavior and to relate this development to what we know from developmental and cross-cultural psychology about the psychogenesis of fundamental structures of cognition.

Essentially, there are three types of sources that provide at least indirect evidence of the development of cognition in prehistory and the level of cognition that was ultimately achieved in the prehistoric era.

First, animal and human cognition can be compared in order to infer minimal cognitive achievements connected with the origin of mankind.

Second, the cognition of extant indigenous people living without contact to modern civilization under conditions comparable to those of prehistoric times can be studied and can be related to the corresponding prehistoric periods.

Third, the earliest written documents of mankind can be studied in order to determine the level of cognition at the end of the prehistoric period that made the transition to literacy possible.

What follows will essentially be a critical survey of conclusions that can be drawn from such studies. A critical survey seems all the more neccessary since discussions among anthropologists about what can be concluded from the palaeoanthropological findings with respect to the development of cognition are ongoing, for instance the discussion on the origins of symbols (Byers, 1994; Bednarik 1995). These discussions, however, rarely include psychological research in general and genetic epistemology in particular.

Origin of human cognition

The Paleolithic Period

Leaving aside the development of our proto-human ancestors, human development in prehistory covers roughly the time-span from the first appearance of man about a million years ago up to the occurrence of the first writing systems around 3,000 B.C. Most of this vast period belongs to the so-called Paleolithic, ending about 8,000 B.C.

Although there is no clear-cut distinction between proto-human primates and early hominids, considerable agreement exists about the essential characteristics of human culture that developed in the Paleolithic Age. The production and use of tools, on the one hand, and the emergence of language as a developed means of communication, on the other, are believed to mark the difference between animals and human beings.

Throughout the Paleolithic, man was a hunter and food gatherer producing tools of which only those made of stone, bone and antler have survived. In general, these tools developed gradually from a few all-purpose tools at the beginning of the Paleolithic Age to a great variety of highly specialized and sophisticated instruments for specific purposes at the end. In the Upper Paleolithic Period which covers approximately the last 100,000 years of the Paleolithic, regional stone tool industries emerged and basic techniques of drawing, modelling, sculpure, and painting were developed.

Comparison with animal intelligence

Given this overall picture of the Paleolithic, some obvious conclusions can be drawn concerning the level of cognition associated with the emergence and development of the human species.

Humans in the Paleolithic were surely equipped with at least those cognitive prerequisites based on sensory-motor skills that make up the intelligence of primates. This should warn us against a careless application of human psychology. The success of Paleolithic man to survive even under extremely harsh living conditions, and his superiority to the animals he was hunting is not necessarily an indication of specific human cognitive abilities.

Let us take spatial orientation as an example (Pick, 1983). Certain cognitive structures relative to spatial relationships and their representation in gesture, language and other external tools of orientation are so fundamental components of human cognition that they seem to be a necessary prerequisite of those activities attested for the Paleolithic humans. It is known, however, that animals may also exhibit an extremely sophisticated performance in spatial orientation (Ellen & Thinus-Blanc 1987). The behavioral mechanisms available to them in their spatial orientation are not only based on simple adaptation to cues and stimuli. On a higher level of cognitive organization, animals also exhibit rule-governed behavior. They adapt to problems using alternative strategies such as “change-after-success“ or “stay-after-success“ depending on how food supply varies at different locations. Many animals show intelligent spatial problem solving based on some kind of cognitive map representing spatial relations. Such mental representations of spatial relations depending on past experience make animals capable of rearranging the patterns of their orientation behavior, taking short-cuts in complex spacial arrangements, choosing between alternative routes for reaching a certain goal, etc. Primates seem even to be able to decode spatial relationships from spoken human language and to communicate such relationships by gestures, deliberately produced trails, learned symbols, etc. (Savage-Rumbaugh et al., 1993; see also her chapter in this volume). In order to decide whether certain activities of Paleolithic humans show any characteristics of typical human cognition they have to give evidence of cognitive preconditions which according to our knowledge are qualitatively different from what we know about such intelligent behavior of animals.

Indications of human intelligence

Cognitive prerequisites of human activities which exceed the capabilities of animal cognition can indeed be inferred even from the scarce information we have. Neither the ability to communicate information by some kind of language precursor nor the skill necessary for the use or even the production of tools are beyond the cognitive capabilities of animals. Rather, the continuous transmission of knowledge from one generation to the other is the necessary prerequisite of the development of a human language with socially transmitted meanings and of the enduring improvement of the stone implements over the millennia of the Paleolithic era.

Such a transmission constitutes human cultural development. At least in its developed form, it presupposes powerful means of communication such as human language which is assumed to have emerged in the Paleolithic together with the development of tools (Byers 1994; Wallace 1989). While the development of such means of communication as language and its presumable precursors in facial expressions, body language, and vocalizations such as screams and cries can only be indirectly inferred from Paleolithic remains (Armstrong et al., 1994; Bateman et al., 1990; Davidson and Noble, 1989), so-called Paleolithic art provides evidence of various kinds of pictography and symbolism in the Upper Paleolithic Period. Paleolithic art is expressed in artifacts such as decoration, pictography, personal adornment, graves, sacrificial goods, modeled figurines, and cave paintings. These indications of the representation of mental constructs lead to the conclusion that the development of tools was indeed accompanied by an evolving ability to make use of symbolic representations.

Emergence of preoperative thinking

Now, this is exactly what one would expect from the perspective of genetic epistemology. It is precisely the development of the symbolic function at the preoperational stage of the growing child at about the age of two years that inaugurates the ontogenetic bifurcation into independent developmental paths of animal and human cognition. According to Piaget, at about this age human children——contrary to young primates——achieve the ability not only to react to the signals of sensory-motor intelligence which represent for the subject simply a partial aspect of the object indicated, but also to decode the symbols and signs and distinguish them from the objects themselves. The symbolic function constitutes preoperative thinking and leads to preconcepts that are the notions attached to the symbols and signs.

The development beginning with animal reactions to signals emitted by their environment and concluding with the creation of symbolism in the Upper Paleolithic Period resembles this transition to preoperative thinking. While animal cognition is essentially based on individual experience, Paleolithic art seems to indicate that at the end of the Lower Paleolithic Period symbols and signs were deliberately used to transfer socially transmitted meanings. The difference due to reflection is recognizable when——as in the case of cave paintings——the symbols and signs cannot have been produced without a conscious discrimination of the symbols and their meaning.

Cognitive development in the long Paleolithic Period can, therefore, be characterized as the transition from sensory-motor intelligence to preoperative thinking based on the development of the symbolic function.

Operative thinking at stone age level?

Paleolithic art, however, also contains certain elements which are suggestive of arithmetical and geometrical cognition and have sometimes been interpreted as indications of a higher developmental level of cognition than the level of preoperative thinking.

The paintings in the cave of Lascaux, for instance, which have been dated by carbon-14 analysis to about 14,000 B.C., depict primarily animals hunted at that time, but also contain some simple drawings composed of straight lines and sequences of dots which may be interpreted as abstract geometrical figures and early numerical representations. However, if as has been proposed the drawings depict traps, then the regular shapes are not the result of any geometrical construction or conceptualization, but simply depict artifacts which as a result of material constraints result in rectangular shapes. And if, as one might conjecture, the series of dots represent the number of animals hunted in a one-to-one correspondence, these dots are still only representations of animals and not representations of numbers. This interpretation of the dots as symbols for objects and not as a representation of numbers is strongly supported by the fact that the dots lack the regular structuration characteristic of all counting sequences.

Another archaeological find believed to constitute an example of early arithmetical activity is a notched bone tool handle excavated at the Mesolithic site of Ishango. The implement is dated to about 7,000 B.C. It shows three sequences of grouped notches. The groups of the first of these sequences contain 3, 6, 4, 8, 10, 5, 5, and 7 notches, the groups of the second contain 11, 13, 17 and 19 notches, and the groups of the third contain 11, 21, 19 and 9 notches. There is no obvious, simple regularity in these numbers. The excavator, Jean de Heinzelin, admitted that the grouping might be fortuitous (de Heinzelin 1962). Nevertheless, he offered the interpretation that the notches were deliberately planned and may represent an arithmetical game. He further argued that if so the tool provides evidence of the use of a decimal system and of the knowledge of duplication and of prime numbers. Alexander Marshack (Marshack 1972) also assumed that the notches were consciously prepared notations, but offered an alternative interpretation. According to his opinion, based on an analysis of how the notches were carved, the groups can further be subdivided and thus turn out to be astronomical records representing the lunar cycle.

The evidence is weak for both interpretations because the sequences of notches offer no evidence of even the minimal requirements of signs representing arithmetical notations; they do not exhibit the typical regular structure of counting series.

Missing evidence of typical structures of counting sequences does not, of course, prove that such cognitive constructions did not exist in early prehistory. Counting techniques are usually based on language or gesture that do not leave traces in the archaeological records. However, as we know from extant pre-literate cultures, even the existence of counting techniques does not necessarily indicate an operatory concept of number. Only an analysis of the use of such techniques allows us to draw conclusions with regard to the level of cognition involved.

We must conclude that with this evidence there is no sufficient justification for the alleged arithmetical activities of man in the Paleolithic Period. Neither the implements that survived from the Paleolithic nor Paleolithic art provide evidence to support the assumption that a level of cognition higher than the level of preoperative thinking was achieved at that time.

The Neolithic Revolution

Within the following time period up to the end of prehistory there were at least two major changes in human social organization: the so-called Neolithic Revolution around 8000 B.C. and the Urban Revolution beginning about 4000 B.C.

The Neolithic Revolution was brought about by the transition from food gathering to life in stable settlements. This revolution probably resulted in a dramatic population increase, and it was accompanied by several innovations which must have had a cognitive impact: techniques for building dwellings, the cultivation of land, animal domestication, the invention of tools like the hoe and later the plow, the development of food preparation techniques such as baking and brewing, the development of weaving techniques, as well as the use of clay and the production of pottery, developing into a striking variety of regionalized and successive styles of painted pottery. There are, furthermore, indications of early forms of trade, in particular the dispersion of luxury objects like shells into areas far away from their places of origins and the distribution of tools such as stone axes manufactured at the source of the stone. At the end of the Neolithic Period, flint and other stone tools were gradually replaced by copper and, eventually, bronze implements.

This brief survey of Neolithic innovations makes evident that it is this period that shows the closest resemblance with what we know from extant indigenous cultures at a stone age level. If, therefore, Piaget's assumption is correct that cognition in such cultures does not exceed the preoperative level, then the Neolithic Revolution in spite of the material progress did not fundamentally change the level of cognition achieved at the end of the Paleolithic Period.

The Urban Revolution and the emergence of cognitive tools

The second change, the so-called Urban Revolution, is indicated by the emergence of large, i.e. the early cities, the differentiation of the population into spezialized occupational groups, the stratification of the society into social classes with different access to resources, and the emergence of monumental architecture. This process of urbanization was a long-term consequence of the achievements of farming. Intensive agriculture produced a surplus which made possible the proliferation of administrators and specialists, freed from primary subsistence activities. Urbanization emerged in the Near East in the 4th millennium B.C. and approximately at the same time in Egypt, in the Indus valley in the 3rd millennium B.C., in China probably in the 2nd millennium B.C. and in the New World in the first millennium B.C. From these centers urbanization spread into the surrounding regions, in particular into Europe and across Asia.

This Urban Revolution as a process of transition from a Neolithic village farming society to the first centralized settlement patterns of the late Neolithic and early Bronze Age was quite different from the earlier Neolithic Revolution. The Neolithic Revolution was an advance in man's control of his environment, the Urban Revolution primarily changed human relations by a transition to a vastly greater complexity of patterns of social organization. These social patterns no longer resemble social structures known from extant pre-literate cultures. Thus, we can only refer to archaeological data in order to understand the transition from the Neolithic period to early civilizations.

The extensive excavations in Mesopotamia and in Iran are of particular importance for the study of this urbanization process. They show that urbanization began in prehistory a considerable time before the invention of writing (Algaze, 1989; Nissen, 1988). In the Late Uruk Period in the 4th millennium B.C., the culture of Mesopotamia and the surrounding areas already differed fundamentally from that of Neolithic villages. Urban centers with a highly developed division of labor and social stratification emerged. Remnants of representative buildings in the city centers attest to the existence of temples and palaces which were the administrative centers of a redistributive barter economy. A sophisticated apparatus of officials organized the deployment of labor and supervised the distribution of the products of labor collected in central storehouses.

The development of cognitive tools

The administrative tasks associated with this type of economy could not be accomplished without administrative aids for the qualitative and quantitative control of the economic resources. Contrary to earlier developments in prehistory, the process of urbanization was, therefore, closely associated with the development of genuine cognitive tools which have at least partially survived (Nissen 1988; Nissen et al., 1993). Standardized containers, stamp seals which were pressed into clay surfaces and later cylinder seals which were rolled over the surface of clay objects before they were dried or baked, containers supplied with sealed stoppers or with sealed bullae, signs with numerical meanings, but most importantly a special kind of clay symbols with simple geometric shapes (sphere, cone, pellet, tetrahedron, cylinder, etc.), which were apparently used, among other things, as counters to record quantitative data, served the registration and symbolic representation of economic goods and the designation of those who controlled them (Schmandt-Besserat, 1992). These tools offer evidence of a development of cognition which has no parallel in extant pre-literate cultures.

The clay symbols had probably the greatest cognitive impact. Their function is attested to by the fact that combinations of such clay symbols were sometimes kept in closed and sealed clay spheres——apparently for the purpose of preventing the manipulation of the encoded information. Some of these clay spheres exhibit impressions on their surfaces. These impressions generally correspond in type and number to the clay symbols inside the spheres. They can easily be identified as precursors of the numerical signs of the later writing systems. Furthermore, numerous clay tablets——the so-called preliterate numerical tablets——which bear seal impressions together with such impressions can also be dated to the period shortly before the invention of writing (Englund, 1994; Schmandt-Besserat, 1981).

The invention of writing

Around the last century of the 4th millennium a system of pictographs was added to these symbolic means of representation. The introduction of such pictograms is generally considered to be the actual invention of writing. This is, however, merely a matter of definition. It seems that, at least in the beginning, these pictograms did not serve to write down spoken language but exclusively served the purpose of bookkeeping (Nissen et al., 1993). Two different systems of this kind of archaic writing systems emerged in the Near East in quick succession, the so-called proto-cuneiform and the proto-Elamite archaic writing systems. Soon afterwards if not simultaneously, a third system of writing, the Egyptian system, was developed——unfortunately, however, the evidence from the early period of this system is sparse, so that it is difficult to draw conclusions with regard to the cognitive processes involved.

The origin of the other two systems, however, can fairly well be studied based on the extant sources. Each system contained more than 1,000 different signs with widely standardized notations and conventionally defined meanings.

The more important system is the proto-cuneiform system of southern Mesopotamia, from which cuneiform writing evolved. To date approximately 5,600 clay tablets and fragments with this type of writing have been excavated. The oldest are texts from the IVa layer of the ancient city of Uruk, the most important archaeological site yielding proto-cuneiform tablets (Englund, 1994).

The other system, proto-Elamite writing, which is documented by some 1,500 texts——most of them from Susa, the urban center of a region to the southeast of Mesopotamia——was created somewhat later. It adopted the idea and took over, slightly modified, the proto-cuneiform numerical signs (Damerow & Englund, 1989). The system was used for only a short time.

The oldest tablets displaying a developed system of cuneiform writing date back to around the middle of the 3rd millennium B.C. Cuneiform writing was the first genuine writing system, terminating the long prehistoric period (Nissen et al., 1993).

The ultimate level of prehistoric cognition

After this brief outline of the transition from the Neolithic Period to early civilizations let us now turn to its cognitive implications in order to answer the question of what level of cognition was ultimately achieved in prehistory.

It has been pointed out already that in the course of urbanization the use of symbolic representations increased dramatically. This development must have been accompanied by a sweeping expansion of the content and form of knowledge. After the invention of writing, we find stratified societies with a highly complex social organization. The cognitive capabilities of leaders and administrators in these societies must have been strikingly higher than those of man in early prehistoric times. These people not only invented the technique of writing but also used developed techniques of measurement and numerical calculation and even early forms of mathematics. Such techniques are usually considered proof of sophisticated operative thinking.

There is obviously a discrepancy between human intelligence at the end of the Paleolithic and in the late Neolithic Period indicating a rapid acceleration of cognitive development within this comparably short time span. At the end of the Paleolithic Period man had achieved the symbolic function. As far as cognition is concerned, this symbolic function was a major achievement of the transition from animal to human intelligence. Nevertheless the simple use of the symbolic function at the end of the Paleolithic, documented by Paleolithic art and symbolism, is not comparable to the sophisticated cognitive techniques which were used after the rise of civilization when writing was invented.

This striking difference between late Paleolithic and late

Neolithic symbolism raises three questions.

1) What precisely were the new contents and forms of knowledge which are indicated by the new symbolic representations?

2) To what extent do they indicate a level of cognitive development beyond the level of preoperative thinking?

3) Did this higher level of cognition exist earlier or was it a genuine result of the Urban Revolution?

In order to answer these questions we have to study the new symbolic representations in somewhat greater detail.

Prehistoric tokens and numerical notations

For the incipient phase of the Urban Revolution, our knowledge about the cognitive tools used by the urban adminstration is rather limited. Tokens or pebbles believed to be tokens have been found in archaeological layers that date back well into the Neolithic Period, in some cases as early as the eighth millennium B.C. However, there is no archaeological evidence for relating them from the very beginning to administrative activities. Only finds dating to the 4th millennium provide clear evidence of such usage. Not only did the number and variety of tokens increase considerably, but they were now sometimes kept in those sealed clay envelopes that have provided us with the key to understanding their arithmetical function. Furthermore, numerical tablets——the precursors of proto-cuneiform writing——now occur for the first time. In view of prevailing speculations attributing arithmetical meaning to repetitive Paleolithic and Neolithic patterns, it is worth noticing that the pre-literate combinations of tokens and impressions on clay surfaces from the 4th millennium provide the first reliable evidence of the construction of one-to-one correspondences that eventually resulted in the operatory concept of number.

We get some further clarification of the function of these denotations of quantities in the latest period of prehistory if we compare them with the numerical notations of the later proto-cuneiform and proto-Elamite writing systems. This comparison reveals that the different impressions or tokens already represented measuring and counting units of different kinds and orders found in the later writing systems. However, it also provides indications of a fundamental change of the semiotic function of the signs in the transition from pre-literate to proto-cuneiform and proto-Elamite numerical notations.

Contrary to the numerical signs of the later archaic writing systems, the impressions on envelopes of tokens and the impressions on those numerical tablets that can be dated beyond doubt into the pre-literate period lack the standardization of later numerical notations. Accordingly, all attempts to identify the measuring and counting units represented by the pre-literate tokens and impressions have failed so far (regarding the alleged identifications of Schmandt-Besserat see the critic of Michalowski, 1993). Furthermore, the comparison shows that contrary to later numerical notations the repeated units have not necessarily been converted into higher units. On a tablet from Jebel Aruda dating to the middle of the 4th millennium B.C., one of the signs of the notation is even repeated 22 times (van Driel, 1982).

The lower degree of standardization and of strict adherence to semiotic rules strongly suggests that the signs before the invention of the archaic writing systems did not yet represent abstract measuring and counting units but still represented the real objects or containers which made up the quantities to be represented. They indicate, at least, that the prehistoric token and sign combinations were in a transitional stage between the representation of real objects by one-to-one correspondences to tokens and signs and the representation of quantities by semiotically structured numerical notations.

Proto-literate numerical notations

Let us now turn to the situation immediately after the invention of writing. The hypothesis of a fundamental change in the symbolic representation of quantities at the end of prehistory receives further support by the results of a analysis of the numerical notations in the proto-cuneiform texts (Damerow & Englund, 1987). These results strongly contradict common expectations. In view of the close resemblance of many of these notations to numerical notations in the later tradition of developed cuneiform writing, it has always been assumed that the numerical signs represented numbers (Falkenstein, 1936; Falkenstein, 1937; Langdon, 1928). Inconsistencies of the interpretation of numerical operations resulting from this assumption were explained by errors of the ancient scribes or by the clumsiness of an insufficiently elaborated notation system.

However, as a result of recent analysis it turned out that the numerical notations in the proto-cuneiform texts follow strictly applied semiotic rules and that the alleged errors of the scribes in fact resulted from the mistaken assumption of modern scholars that they represent numbers and accordingly must have definite numerical values. Contrary to all expectations the proto-cuneiform numerical signs proved to have changed their numerical value depending on the objects they were applied to, and the same turned out to be true for the numerical signs of the proto-Elamite writing system (Damerow & Englund, 1989).

This startling conclusion needs to be explained in some detail. The analysis of proto-cuneiform and proto-Elamite numerical notations showed that the numerical signs represented units of counting and measuring systems with entirely standardized numerical relations between the units. The ranges of these systems from the lowest to the highest units as a rule covered tens of thousands of units and sometimes even more. The precision of many of the numerical notations exceeds what we might consider reasonable limits which might be explained as the result of an exaggerated bureaucracy. At first sight, the oldest written documents of mankind seemed to prove that at the time of the invention of writing a fully developed number concept and elaborated techniques for numerical calculations existed.

Closer inspection, however, provided puzzling details. Whereas the same signs were often used to designate units of different metrological systems, the numerical relations between the units varied considerably from one metrological system to the other. Moreover, the meaning of the signs, that is, the conventions by which certain units were represented by certain signs, was determined in one system without taking into account how the meaning was determined in other systems. Thus, the numerical values of the signs were entirely dependent on the system for which they were actually used, that is, on the particular context of their application.

A certain sign (N34; see Damerow & Englund, 1987, 127), for instance, represented a unit that is 60 times smaller than another unit represented by another sign (N45) when they were used in a system for counts of certain discrete objects as, for instance, animals. But the same sign was used for a unit 3 times larger than the other one when they represented certain grain measures (Damerow & Englund, 1987, 136)).

The details of the different numerical sign systems of the archaic texts cannot be discussed here. Despite the ambiguity of the numerical signs, 14 proto-cuneiform and 8 proto-Elamite numerical sign systems could be identified and their fields of application determined. These areas of application turned out to have been mutually exclusive, but their definitions followed no obvious rules and seem to have been determined simply by tradition. It is remarkable that not even all discrete objects that can be counted were recorded in one and the same system. In the proto-cuneiform texts five systems with two different arithmetical structures and in the proto-Elamite texts four systems with three different arithmetical structures were used to denote different types of discrete objects.

The numerical ambiguity of the numerical signs is not the only indication that the meaning of the signs was dependent on the context in which they were used. Without further explanation, some additional evidence will be given in the following.

The numerical signs inherited from their prehistoric precursors——that is, the tokens and impressions——the function to represent objects and not numbers. In contrast to these precursors, repeated signs were converted as far as possible into higher units; however, the arrangements of the signs were still not consolidated in standardized representations of numbers or quantities. Frequently, there are additive and multiplicative relations between different entries of text, that do not represent abstract operations, however, but correspond always to some material action or transformation. Even the seemingly clear distinction between the numerical signs originating in tokens and the non-numerical pictographs appearing with the invention of writing appears to be much less clear on closer inspection. Numerical signs could denote objects by some inherent measure as, for instance, the denotation of barley products by the amount of barley necessary for the production of one unit. Conversely, non-numerical signs such as signs for rations or for special types of beer could also stand for related quantities such as the standard size of a ration or the strength of the beer measured by the amount of grain necessary for the production of the amount held by one jar. Furthermore, numerous composite signs which are graphical combinations of numerical and non-numerical signs were used in order to express quantitative and qualitative information by means of a single sign.

The overwhelming evidence pointing to a meaning of the numerical signs of proto-writing dependent on their context of application suggests that the arithmetical techniques of archaic bookkeeping were in fact techniques without an integrating number construct. Both the meaning of these signs as well as the way they were used do not correspond to what could be expected if they would have represented numbers or generalized numerically structured concepts such as the abstract concepts of space, time, weight, volume, area and so on.

What else can the numerical signs and the techniques of handling them have represented if not numbers and numerical operations? We get a convincing answer to this question if we assume that the numerical signs and the way they were used in principle had the same function as the non-numerical signs and their use (Damerow, 1995, Chap. 9). Accordingly, their function must have been to represent the objects and actions of the archaic bookkeeping system. The objects and actions were encoded in categories directly related to each specific context and quantified by mental metrological constructs consisting of relations which were set up by context-specific conventional standardizations and measurement procedures.

A puzzling conclusion

This result of an analysis of the proto-literate sign systems answers the first question posed earlier concerning the ultimate level of prehistoric cognition. We asked about the cognitive contents and forms of knowledge represented by the new symbolic representations that were created by officials of early Mesopotamian cities at the dawn of history. It turned out that they represented mental models of their administrative activities. These models were developed and represented by systems of symbols as a means for coordinating collective human actions in a complex social setting.

This answer to the first question, however, makes it even more difficult to answer the second concerning the cognitive level beyond the level of Neolithic preoperative thinking indicated by the new symbolic representations, and the third question concerning the historical origins of such a higher level of cognition. Insofar these questions are concerned, the results of the analysis of proto-literate sign systems apparently leads to a paradox.

On the one hand, the gap between Neolithic preoperative thinking and the sophisticated cognitive techniques used in early civilization seems to be bridged. The development of the precursors of proto-cuneiform writing demonstrates that first the adminstrative problems associated with the process of urbanization were solved by exhausting the potentials of proto-arithmetical tools well-known from extant pre-literate cultures. At the end of this pre-literate period the officials who were in charge of these tasks had created, by elaborating these potentials, a complex symbolic system representing their activities. This is seemingly a paradigmatic case of reflective abstraction which according to genetic epistemology brings about the fundamental structures of logico-mathematical cognition.

The puzzling structure of the numerical notations used in the archaic writing systems shows, on the other hand, that certain cognitive constructions which according to genetic epistemology should be the immediate result of a transition from preoperative to operative thinking were still lacking. In spite of the complexity of the archaic system of bookkeeping, the analysis of these notations provides strong evidence against the existence of a number construct integrating the context-dependent rules according to which the signs were manipulated.

Is it conceivable that the officials running the administration of a complex redistributive society using highly developed symbol systems in order to control the flow of materials and products were not able to use reversible mental operations, that they still, like members of Neolithic rural communities, solved their problems on a preoperative level of cognition using proto-arithmetical aids?

The discrepancy in the final period of prehistory of the emergence of highly complex symbol systems and the lack of integration of the context-dependent systems by generalized operations, indicating the emergence of mathematical and logical thinking, suggests that different rates of progress do not alone account for fundamental historical differences in levels of cognition.

It has been pointed out at the beginning that, following Piaget, this assumption, however, is still widely accepted in genetic epistemology. According to genetic epistemology the fundamental structures of logical and mathematical thinking are universal, and this universality is assumed to be based on universal structures of the coordination of human actions.

It is true that certain human activities are so deeply rooted in biological preconditions of human action that their coordination gives rise to structures of human cognition which are probably universal. Such basic activities, however, do not necessarily determine the development of cognition to such an extent that independent of any specific social and cultural environments the outcome of ontogenesis is always the same, universal structure of logical and mathematical thinking.

Genetic epistemology as conveived by Piaget meets serious difficulties as soon as substantial historical differences in the fundamental structures of thinking have to be explained. Accordingly, Piaget and Garcia in their famous study on the psychogenesis of basic concepts of scientific thinking were compelled to place the psychogenesis of the alleged universal basic concepts of classical mechanics into the time of Newton, and consequently into a completely different historical period than that of the psychogenesis of basic concepts of arithmetic and geometry, which are supposed to have their roots in prehistory and were fully developed in the Greek classical period (Piaget & Garcia, 1989, chapters 1 and 2). But if the structure of such concepts would be entirely independent of any specific social and cultural environments, determined only by fundamental coordination of action, why then should they emerge historically in so different periods?

Such paradoxes inherent in Piaget’s genetic epistemology vanish if we assume that operatory cognitive structures may evolve in different forms depending on the nature of the activities and their coordination, from which they are constructed by reflective abstraction. The ultimate cognitive outcome of prehistory can be conceived then as the emergence of a specific form of operative thinking, its structure being determined by its specific origin in the manipulation of the symbols of the archaic bookkeeping system.

Such an understanding of the cognitive outcome of prehistory not only explains the peculiar context-dependent use of archaic symbols. It can, moreover, pave the way for an understanding of the further cognitive development in early civilizations from the perspective of psychogenesis. It can help us to understand why such a variety of independent and often incompatible symbol systems emerged in the period of early civilizations. To conceive of general concepts of modern logical and mathematical thinking as an outcome of the integration of context-dependent cognitive structures under historically specific constraints, and not as pre-determined in their structure by their origins in the coordination of human action, provides us with a convincing explanation for the fact that the early civilizations did not result immediately in abstract numbers and Aristotelian logic but in such odd logico-mathematical structures as those of Babylonian mathematics, Egyptian calculations with unit fractions, Chinese proofs by analogical reasoning, and the sophisticated ritual calendar of the Mayas.

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