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15 The invention of writing and the development of numerical concepts in Sumeria: Some implications for developmental psychology

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Introduction

In this article I will examine in some detail the work of the German psychologist Peter Damerow on the use of historical materials to address psychological questions concerning the development of the concept of number. This work, so far still little known, is a significant example of the recently emerging interest in the systematic analysis of the relation between individual psychological development and the socio-cultural context within which the individual develops, including consideration of the historical and evolutionary processes by which that social context itself develops.

While the effort to situate individual development more self-consciously in a socio-historical framework has a number of sources, one major intellectual impetus has been a renewed awareness and appreciation of the work of L. S. Vygotsky and the socio-historical school of which he was a pioneer. Vygotsky proposes to understand the formation of human nature – which is, after all, the central mission of psychology – through studies of the origin and development of higher psychological functions as such. This development is, for him, a social as well as an individual process – more specifically, it can be understood only by grasping the systematic interpenetration of social and individual processes (Vygotsky, 1978, 1981; see also Bakhurst, 1988 and Wertsch, 1985). As Scribner puts it in an illuminating analysis of Vygotsky's theoretical project (1985), Vygotsky "takes as his conceptual object [the development of] 'higher psychological systems' and separates it

from the natural object, [the development of] the 'child'" (Scribner, 1985, p. 133). Furthermore, Vygotsky argues that these "psychological systems" are embodied not only in the individual mind but also in culture; in fact, the cognitive structures which make up the "higher psychological systems" are culturally shaped and develop historically (Vygotsky, 1978, 1981).

As Scribner logically reconstructs Vygotsky's steps in building a method for studying the formation of cognitive structures, Vygotsky would begin with observations of "primitive" adults documented in ethnopsychological records and then, by way of experiment, move to observations of children of his own time. In other words, cultural history was used to generate hypotheses about the origins and transformations of higher psychological systems. But despite Vygotsky's early insight, cultural history did not become a domain of psychology proper. There have been few psychological studies that have examined systematically the historical development of "higher psychological systems" *per se* and then returned to address questions raised by psychological theories of development. There are various reasons why this has been the case, but a practical one is that such work requires the thorough mastery of (at least) two disciplines, which Damerow and associates are able to achieve through their collaborative effort. Hans Nissen and Robert Englund, principal associates in the work I'll be discussing, are both archaeologists at the Free University of Berlin, while Peter Damerow is a developmental psychologist at the Max Planck Institute for Human Development and Education in Berlin. Their work appears to stand in close intellectual connection to Vygotsky's efforts; at all events, it embodies in a fruitful way the sort of method envisioned by Vygotsky for psychological research. The lack of any mention of Vygotsky, or of the socio-historical school he represents, makes it unclear whether there is any direct filiation between their work and his. The significant point, however, is that their work addresses some of the issues which Vygotsky suggested were of crucial importance for developmental psychology.

The theoretical significance of the research

The research headed by Damerow examines the historical development of numerical concepts in Babylonian culture through the systematic study of ancient texts. This study forms the nucleus of a set of

investigations which pursue the question of the cultural mediation of fundamental cognitive structures. In particular, they address the question of whether there are certain basic structures of thought which are independent of specific cultural influences – or whether even the most basic structures are dependent on available systems of symbolic representation or on the content of experience so that, despite their universality, they must be viewed as culturally mediated.

Specifically, this historical study takes issue with Piaget's epigenetic[1] conception of structural constructivism in explaining the development of the number concept in children. This development, according to Piaget, is the result of the construction of a cognitive structure based on experience and abstraction. Thus, it is neither an inherited intellectual schema (performed or innately given) nor a property directly abstracted from real objects; rather, it is the result of "reflective abstraction" from the actions carried out with the objects. In particular, Piaget explains the concept of number as the result of the coordination of actions such as the construction of one-to-one correspondence between sets of objects or between qualitative relations, the adding or taking away of objects or groups of objects, etc. In the fully developed cognitive structures, these actions are mentally represented by reversible operations constituting a closed system of possible inferences. But the arithmetically structured substratum of the number concept is an ideal substratum. Numbers are ideal objects of thought whose existence is not bound to the existence of material objects to which they are applied. They are independent of their particular representations by the various systems of numerical signs which might differ from one culture to another (Piaget & Szeminska, 1965).

In short, according to Piaget, the concept of number – though not inherited but acquired through the experience of objects – is in its substance not influenced by the content of these experiences. He interprets the coordination of actions as resulting from an endogenous unfolding of *biologically predetermined possibilities* in interaction with the environment, and hence sees the basic structures of cognition as a special form of biological adaptation. Its endogenous development is nonetheless an epigenetic process governed by inner necessity (Piaget, 1971, 1972).

This view, however, excludes the possibility that the structural transformations of cognitive structures are influenced by the material repre-

sentations of those structures – in actions, pictures, or symbols – or by the forms of social interaction mediated by these representations. In contrast, Damerow advances the view that the particular representations of cognitive structures have the function of marking off *the horizon of possibilities* for the ontogenetic realization of cognitive structures (Damerow, 1988). Thus, conceptual change might not only be endogenous to a cognitive system; the initial qualitative changes might be exogenous to it and historically as well as culturally determined. Part of individual development would then consist of the effort to appropriate culturally developed cognitive structures.

In the following sections, I will first present the historical findings from the study, which will require reconstructing the socio-historical context in some detail; then I will discuss the significance of these results for theoretical issues in developmental psychology.

The historical study

The archaic texts from Uruk. The subjects of the study is the systems of number signs in the Archaic texts from Uruk, a Sumerian city-state in the ancient civilization of Mesopotamia, located in the southern part of today's Iraq. This group of texts consists of some 4000 clay tablets and fragments of tablets, most of which have not yet been analyzed. With very few exceptions, these tablets were found in the district of Eanna, which from early times was a (perhaps *the*) central district of the city. Later this district housed the large cultural installations for Inanna, the city-goddess of Uruk.

These tablets were written around the end of the 4th and the beginning of the 3rd millennium B.C., and are the oldest surviving written documents from this part of the ancient Near East, if not the oldest in the history of mankind. By about 3100 B.C., the officials of such administrative centers as Uruk had developed a system of recording numerals, pictographs, and ideographs on specially prepared clay tablets. These texts are of great importance for the study of the relation of culture and cognition because they document the change brought about by writing in the existing number system.

The majority (85%) of these texts are economic records, while 15% constitute the so-called "lexical lists." Lexical lists were presumably used for the training of scribes and consist of lists of semantically related words whose order of enumeration has not yet been deciphered (Nissen, 1985, 1986). The "economic texts," on the other hand, were part of a bookkeeping system which recorded such matters as business transactions. For example, they seem to be receipts and lists of expenses, of animals, of all kinds of goods, or of raw materials. Given the overwhelming preponderance of economic texts, the invention of writing has been attributed to the creation of administrative city centers – themselves the result of urbanization – and the need to coordinate an expanding economic unit. This set of conditions prompted the introduction of coordinating economic devices better suited to manage larger quantities of information than had previously been available.

Record-keeping systems in Mesopotamia: Origins of the economic texts. Archaeologists have identified an even older record-keeping system used in the ancient Near East which was based on using pebbles or clay bits ("tokens"), accumulated in heaps or containers, as a temporary record of numbers (Goody, 1986; Schmandt-Besserat, 1978, 1983). This system is of particular interest as a more or less direct precursor of writing since many of the written signs (numerals and ideographs) seem to be two-dimensional representations of the clay tokens themselves. The clay tokens of the preliterate period are small, geometrically shaped objects (e.g., spheres, pellets, cones, tetrahedrons, cylinders, ovoids) which in their later forms are further specified by incised markings. These tokens appear widely in the Near East around 8500 B.C., roughly contemporary with a profound change in human society. An early subsistence pattern based on hunting and gathering was transformed by the impact of plant and animal domestication and the development of a farming way of life. This new agricultural economy, although it increased the production of food, probably introduced new problems which provided the impetus for the creation of record-keeping devices (e.g., storage and distribution of foods and textiles).

The clay tokens stood for particular natural objects such as different goods, animals, or produce. The tokens used in a particular context express in their form the kind, and in their number the quantity, of the goods represented. In animal accounting, for example, one token of each particular kind represents each of the animals of the herds. When new animals were born, the appropriate number of tokens would be added; when they were lost or slaughtered, the appropriate number of tokens

would be taken away. Also, the tokens were probably moved from one shelf to another to signal other changes such as animals moved from one herdsman to another, etc.

Early in the Bronze Age, between 3500 and 3100 B.C., there were significant changes in the recording system. At some point between 3900 and 3400 B.C. – in what archaeologists refer to as the Early to Middle Uruk period – there had been a shift in population patterns. According to Adams (1981), about half of the people in southern Mesopotamia now lived in settlements of at least 10 hectares with a population of about a thousand more. These new developments resulted in the emergence of cities with an urban economy, rooted in trade. Subsequently, the new economy must have multiplied the demands on the traditional recording system. Not only production but also inventories, shipments, and wage payments had to be noted, and merchants needed to preserve records of their transactions.

About 3500 B.C., the tokens themselves underwent a radical change indicated by the proliferation of markings on their surfaces. About 3500 to 3200 B.C., we also find the first clay envelopes, round hollow objects about the size of tennis balls, which were used as containers for the tokens. Previously, the tokens were kept in insecure places, either in heaps or in open containers. This period begins to mark the users' desire to segregate the tokens representing one or another transaction. Those tokens were enclosed in a lump of clay on whose surface one or two cylinder seals were rolled to seal the document and safeguard the contexts for transportation. As discussed by Schmandt-Besserat (1978), Amiet suggested that these clay bullae might have served as bills of lading, for example, accompanying shipments of merchandise from centers of production in the country to the administrative centers in the town.

In case of dispute, the envelope could be broken, but being broken it was of no further use because it could no longer validate the transaction. So a new phase consisted of marking the contents of the envelope on its surface either by imprinting the shape of the tokens themselves in the clay or by some inscribed copy. It was no longer necessary to open the envelope. Indeed the tokens themselves, being a part of a double record-keeping device, became superfluous in this context; they were dispensed with, and what had been the envelopes were flattened out (though still slightly curved), becoming what archaeologists call the

"economic texts." It is of theoretical importance to note, though, that in another context the tokens were not totally replaced, so that even to this day shepherds in Iraq use pebbles to account for the animals in their flocks (Schmandt-Besserat, 1978, 1982).

The numerical signs of the economic texts. The economic texts were marked with both ideographic characters and numerical signs. These were impressed in the clay with three different types of stylus. For the ideographic characters, a sharp-edged stylus was used. In the older texts, the characters were inscribed with a pointed stylus; this was later replaced with an oblique stylus that impressed the "heads" of the lines more deeply than the "tails," leaving impressions in the shape of wedges (=cunei; thus, cuneiform script). In contrast, drawing the numerical signs involved the use of the whole range of different types of stylus. The numerical signs were usually pressed into the clay with rounded styluses which came in a smaller and a larger size. In general, smaller quantities or smaller units of a particular system were impressed with the smaller rounded stylus, while larger quantities or units were impressed with the larger rounded one. In addition, the scribes used a sharp-edged stylus (the same used for the characters) to draw horizontal or vertical strokes, or even dots that some number signs required.

As opposed to the numerical information in the economic texts, which is always given in full, the non-numerical information is extremely brief. Writing was not used in its full capacity but rather as a means of producing catchwords for someone who was more or less familiar with the context and only needed to be reminded of the particular details. So there is neither a trace of a verbal system in the texts nor even a hint of syntactic relations. This situation means that at present the interpretation of the numerical information is still tentative and incomplete; in particular, the archaeologists' suggestions about which objects are being counted, and about the context in which different numerical expressions are applied, are restricted to rough categories based on the most prominent characters on the tablets.

The overall system of the numerical signs and their use is very complex. At present, a total of 60 separate number signs have been identified. Like the tokens of the preliterate period, these signs are both counting and measuring units. With small quantities, the number of objects is indicated straightforwardly by repeating the appropriate sign

the same number of times as the number of natural objects to be represented. As opposed to the clay tokens, however, the signs are systematically subsumed under higher-valued signs whenever a particular quantity is reached; even here, however, the pattern is not uniform, as I will go on to explain.

This set of signs is used more or less interchangeably in a total of (at least) ten number sign systems which are organized very differently from each other; the archaeologists have identified five basic systems and five derived ones. Each of these systems is context-dependent in that each one is used to measure different *kinds* of objects; for example, one measures discrete objects, another objects of mass consumption, another grain, etc. In addition, each of the basic systems is organized differently in the sense that each works with a different base value. This latter feature makes the different systems not readily commensurable to each other.

Of the 60 identified number signs, at least 52 were used in more than one of the five basic (and the further five derived) number systems. As a consequence, the number signs do not carry a context-independent meaning; the value of each sign and the size relation between them differs depending on which system they are being used in. For instance, the meaning of the two most frequently used signs, which are often incorrectly interpreted as 1 and 10, is dependent on the subject matter to which they are applied. They stand in relation 1 to 10 when measuring discrete objects, but in relation 1 to 6 when measuring grain, and 1 to 10 when measuring surface areas of land.

To make matters more complex, within each basic sign system there is not necessarily the same fixed base value between *any* of two consecutive number signs for that system. In some systems, however, the size relation between consecutive signs – although not uniform – can be easily described by a rule; in some of the other sign systems, however, it is difficult to abstract such a rule. (For more details of these numerical systems, see Damerow, 1988; Damerow & Englund, 1986; Englund, in press.)

In brief, the five basic numerical systems identified in the texts are: the sexagesimal, the bisexagesimal, the SE, the GAN_2, and the EN system.

The sexagesimal system was used for discrete objects of various kinds. The system corresponds to the series of number words of the Sumerian language, which is believed to have been the language of the people of southern Mesopotamia at the time of the invention of writing. However, the exact relationship between the numerical system and the number words and, in particular, the direction of interpenetration, is difficult to decipher.

The bisexagesimal system is a second system of numerical signs for discrete objects and agrees with the sexagesimal system up to the sign with the value of 60. The two systems were used completely separately and, after a few hundred years, the bisexagesimal system disappeared completely from the economic texts in favor of the sexagesimal system. It is believed that this system was used to measure particular discrete objects, such as foodstuffs for mass consumption: bread, (possibly) cheese, and a certain kind of fish.

The SE system designates measures of grain. The smaller units of this system are formed as fractions and indicate the types of bread according to the amount of grain contained in them. This system is found only in the older texts; in the newer ones, it is replaced with another system with very similar function – whose arithmetical structure changed, though, with every reform of the measure of grain.

The GAN_2 system designates field measures. Like the sexagesimal system, this system remained in use for a long time without any change in its arithmetical structure. The EN system, finally, is the least well known of the systems, and so far the meaning of the character designating its context of application has not been deciphered.

Implications for psychological theory: Individual and cultural development

Damerow's interpretation of the data. This historical study has, it appears, brought to light two distinct stages in the cultural development of the Babylonian number concept: the first encompasses the arithmetical operations of the preliterate period as demonstrated by the clay tokens; and the second encompasses the arithmetical operations revealed through deciphering of the archaic economic texts. It is of theoretical interest to try to compare these stages to the ones discovered so far in the development of number in other cultures or in children, and also to highlight the factors which might have brought about this conceptual change.

As Damerow observes, the preliterate representation of quantities by a corresponding number of tokens manifests characteristics associated with the concept of number in contemporary "primitive" cultures. "[It] displays the same ties to particular, concrete contexts of application and action . . . , especially through the simultaneous representation of quality and quantity" (Damerow, 1988, p. 148). In particular, it is tied to the concrete use of clay tokens as auxiliary means, and all arithmetical operations are conducted exclusively through them. The result is that they can apply only to limited quantities as well as to a restricted part of human life, as is apparent from the set of clay tokens available.

In accord with Piaget's epigenetic constructivist theory, Damerow argues that the genesis of the representation of quantities by one-to-one correspondence does not require as a prerequisite any cognitive skills of a specifically arithmetical nature. It requires only the appropriate handling of the symbol function (i.e., the ability to ascribe to an object like a clay token a symbolic meaning, such as having it stand for "sheep"), which develops in the early years of life in the child and is found as well in the earliest cultures. He argues further that the essential prerequisites for the concept of number must have arisen in the process of the extensive use of the one-to-one correspondence technique. In his own words, "one can scarcely avoid the compelling conclusion that such a technique of the intellectual construction of correspondence must have brought forth as a result of reflection an equivalent to the conservation of quantity defined ontogenetically by Piaget" (Damerow, 1988, p. 149).

However, his agreement with Piaget's theory stops here. For Piaget, the achievement of this abstraction (the understanding of conservation of quantity) carries with it the more or less simultaneous achievement of the whole range of other structural elements which are necessarily associated with an abstract concept of number. Damerow contends that, even after this initial abstraction has been carried out, there is no reason to assume the presence of all the other structural elements which, in sum, would constitute a fully developed number concept. He puts forth as evidence the fact that the second stage in the cultural evolution being examined, which stabilizes with the use of the archaic economic texts, seems to be intermediate between the absence and the full presence of the number concept.

As discussed above, the numerical signs of the archaic texts are organized in highly complex systems which can be used to measure large

quantities. These signs, however, do not possess any context-independent meaning. The concrete context of application determines how the signs are to be interpreted, and also determines the number of arithmetic operations that can be applied to them before changing to a higher- or lower-value sign. Thus, on the one hand, the arithmetical system revealed through the texts seems to have advanced beyond the level of a primitive number system. On the other hand, it does not yet possess an abstract concept of number, without which one cannot speak of a fully developed number concept in the Piagetian sense. This system, Damerow argues, stands at a stage somewhere between the two, and it "represents a missing link in the cultural evolution from proto-arithmetic to the number concept providing [evidence] that this process does not display the synchronous character of the emergence of the various structural elements of the number concept, which we can ascertain in ontogenetic development and on which Piaget based his epigenetic conception" (Damerow, 1988, p. 150).

Furthermore, Damerow asserts that the real impetus for the transition to a *semi*-abstract system of numerical signs in the archaic texts was the change in the medium of representation. This new medium, consisting of inscriptions on the surfaces of partially-flattened clay tablets, was a by-product of the invention of writing. This led to (relatively) rapid and substantial changes in the earlier record-keeping system, which had remained unchanged for several millennia. There is no reason to think, then, that this transition was preceded by a change in cognitive structure or an expanded arithmetical technique. Rather, it was induced – or, at least, facilitated – by the emergence of a richer and more flexible representational medium; and this cultural change was, in turn, set against a comprehensive change in social organization, particularly socio-economic organization, that marked a shift from an agricultural to an urban way of life. This change in the medium of representation, then, cannot be seen as a secondary or derivative one, nor as merely reflecting an expansion of cognitive capacities; rather, it triggered long-lasting cognitive effects which are reflected in the complexities of the systems of numerical signs it helped to generate.

Some critical reflections. I find Damerow's broad characterization of the transition from the use of clay tokens to the archaic texts as culturally mediated very convincing; however, I find his more detailed characteri-

zation of the cognitive significance of each stage much less so. An important underlying tension in Damerow's article stems from the fact that he is using a culturally-informed approach to make a *partial* break with certain arguments of Piaget's; however, he is unwilling to make as complete a break with the Piagetian framework as the logic of his own position should have led him to do. Damerow, following Piaget, argues that the emergence of the use of clay tokens could take place without the existence of any specifically numerical concepts, requiring instead only a "symbolic" capacity. Furthermore, he suggests that the key development within the first stage – the stage marked by the use of clay tokens – is the development of the concept of conservation of quantity (or "an equivalent to the concept of quantity"). Both these assertions – assumptions, really – seem to me gratuitous and unconvincing.

It seems to me more plausible on theoretical grounds – and at least as well supported by the empirical evidence – to assume that the use of the clay tokens required from the very beginning the presence of at least amorphous numerical concepts, and that these were then refined and crystallized in the course of further development. Furthermore, the use of the clay tokens in itself seems to suggest the presence, at least in limited form, of a concept of conservation of quantity.[2] Here one has to proceed cautiously, since Damerow does not make it precisely clear to what he is referring when he speaks of "an equivalent to the conservation of quantity." The overall structure of his argument, however, implies a somewhat less demanding way of conceiving this concept than the standard Piagetian definition, which requires that children have attained an invariant abstract notion of number as manifested by the fact that they have grasped the irrelevancy of perceptual-spatial transformations (e.g., length, density). What Damerow seems to have in mind by "an equivalent to the [concept of] conservation of quantity" – at least, this is the only interpretation intelligible to me – is a grasp of the rudimentary elements of the concept of quantity itself, including a recognition of the stability of quantities over time, or when individual items are moved or transferred.

Assuming this is the case, we can follow Damerow on this point somewhat farther than he himself wishes to go. I would suggest that the earliest use of the clay tokens must have involved the presence of a limited concept of quantity and, in the weak sense implied by Damerow, of "the conservation of quantity." Indeed, the use of the clay token scheme by

adults in connection with their concrete everyday concerns is incomprehensible otherwise. Granted, this would be what I have called a limited version of the concept of quantity; and what makes it limited (or, one might say, primitive or undeveloped) is indeed that it is so intimately related to the symbolic function. Thus, a clay token stands in a stable way not only for a kind of object but, in particular, for a *single* object of that kind. Hence, it would appear that the unit of quantity that a token represents stands for the (smallest) "natural" unit in which that object exists in the world. The notion of quantity I hypothesize for this stage would therefore involve accepting a natural object as a quantitative "given." (If this is correct, incidentally, it would probably follow that, at least at the beginning of this stage, the clay tokens would represent only discrete but not continuous objects.) But the use of the tokens allows the representation of *collections* of "natural" objects; that seems to be their main point. Representing a multitude of objects is accomplished by accumulating as many symbolic objects as there are "natural" objects to be accounted for; the tokens can retain their value independently of the movement or transferral of the "natural" objects. The fixity of heaps of tokens despite the quantitatively irrelevant changes in the items they represent, and the ability to transfer tokens readily from one heap to another, would indicate the earliest stages of a concept of conservation of quantity.

We can now take another aspect of Damerow's argument one step further. Having stressed the significance for cognitive development of available media of representation, Damerow might have pushed the implications of this view further than he does. For example, I would advance the view that what lies behind the emergence of the first stage, like that of the second, is the discovery of a richer and more powerful medium of representation. In the case of the clay tokens, the crucial impetus is likely to have been the discovery of the possibility of using a symbolic one-to-one correspondence between a miniature object and a "natural" object; on this basis one could create a *set* of miniature objects which could be acted upon to enactively symbolize different arithmetic operations and, in particular, to deal with practical problems concerning quantity. As I have argued above, this does not require assuming that a notion of quantity was only later abstracted out from the repeated applications of the one-to-one correspondence technique. Rather, it seems probable that the appearance of the clay tokens, which marks the

beginning of this cultural stage, must have been intended as a solution to practical problems concerning quantity that had already been dimly grasped. The availability of the new medium, however, would have allowed the number concept and the arithmetical operations it can support to become crystallized to an extent that was previously impossible; it would open up a whole new realm of possibilities.

I would like to mention, though, that Piaget's characterization of the development of conservation of quantity in children from repeated applications of one-to-one correspondence might still be an appropriate way to describe *individual* development in, for example, contemporary western culture. I would hasten to add, however, that this pattern of development probably attests to the shaping of the child's thought toward an adult abstract concept of number. Unfortunately, Piaget ignores the mediating concepts drawn from the adult culture – transmitted by parents, teachers, even experimenters – and erroneously interprets all development as epigenetic. But the individual child is not in the position of creating a conceptual world from scratch; the child is not only interacting with its physical environment but is also, in part, attempting to appropriate the conceptual resources of a pre-existing cultural world. In cultural evolution, though, the change one is trying to account for is one of creation and not appropriation of a concept. (See Scribner, 1985 for some discussion of this distinction.) Thus, perhaps paradoxically, in some ways the process of cognitive development emerges in a "purer" form in the context of historical development than in the case of individual development.

Further possible directions. Finally, I would like to suggest – somewhat speculatively – some further directions in which the lines of argument opened up by Damerow might be carried. To return to one of Damerow's central contentions, one phenomenon which consideration of historical development brings out with particular clarity is the impact of different media of representation on cognitive structures. Let me assume for the moment that the reinterpretation of the first stage I have suggested is correct. Building on this, I will now briefly consider how the media utilized in the different stages of numerical representation might have offered different sets of possibilities, and imposed different sets of constraints, on the cognitive structures they helped generate and shape.

In characterizing these stages, Damerow adapts Aebli's distinction between primary and secondary representation (Damerow, 1988, pp. 129–130). The use of clay tokens to represent number and carry out arithmetic operations involves the use of primary representations, which coordinate action and cognition directly. The symbols used accentuate the quantitative aspect of the objects but also retain some minimal qualitative characteristics, since they stand for specific objects in the concrete world. We might say that this schematization of objects helps produce a miniature world, a microcosm, which creates its own space of operation by allowing concrete actions with arithmetic meaning to be performed directly on the symbolic objects. Handling the symbols is easier than handling the natural objects, and its main purpose is to keep track in the microcosm of the changes taking place in the macrocosm (i.e., the "real world").

The fact that this system of representation is tied so closely to the direct symbolic reproduction of "natural" objects has one implication whose potential importance in limiting the development of abstraction is worth considering: namely, that any changes carried out in the distribution or arrangement of the clay tokens would eliminate all record of the previous state. That is, the medium in which these changes were recorded would not promote abstraction from the fleeting and changeable character of concrete quantities, since previous states do not receive the sort of stable representation which would allow for simultaneous reflection on previous states and end-states. Now, addition and subtraction are operations which can potentially be grasped on a relatively concrete level, and which this medium can thus represent tolerably well. Grasping multiplication and division, however, requires to a greater degree the conscious juxtaposition of two temporally separated states, which is made difficult by the limitations of the enactive medium. For this reason, I would expect that the use of the clay tokens enhanced the psychological reality of the operations of addition and subtraction, but did not promote a grasp of multiplication and division beyond a rudimentary level. This possibility is worth looking into.

It is also worth mentioning that the feature of this mode of representation which I have been emphasizing – its weakness in "fixing" or stabilizing different states so that they can be conveniently and precisely compared – is also a crucial feature which distinguishes an oral from a written mode of communication. I suspect that it would be useful to

bring Damerow's investigations into connection with the body of work which has examined the cognitive implications of oral cultures and the transforming impact of literacy (e.g., Goody, 1977, 1987).

Some of Goody's suggestions, incidentally, might shed light on the matter of the impressive historical continuity of each of these systems of representation, especially of the one based on the clay tokens. The clay-token system, it will be remembered, remained essentially unchanged for at least five millennia and possibly even longer (see Schmandt-Besserat, 1978, pp. 6–9). Once the system of the archaic texts had emerged, it probably remained relatively stable for about a millennium (this is what I gather from Damerow, 1988, p. 151). The available evidence does not allow us to be very definite about dates, but it does bring out that: (1) the longevity of the archaic-texts system was impressive; but (2) it displayed considerably less stability than the clay-token system; and (3) while the basic system of the archaic texts remained stable over a long period, it did display more internal development in its details than the clay-token system. Goody argues that there is a systematic tendency in oral cultures toward homeostasis (Goody, 1977); if so, then the structural similarity between the clay-token system of representation and oral communication might make its tendency toward continuity part of this more general tendency. At least, this parallelism might suggest some clues toward an explanation. At the same time, of course, this factor would at most be one among many. We would also need to reconstruct, for example, the socio-political role that the practices involving the use of each medium might have had, and the position and interests of the strata who used and controlled it (considerations which, by the way, are also stressed by Goody, 1986, and which would in addition lead us back to more fundamental arguments such as those of Weber, 1978). But at the moment these speculations suggest primarily what we don't know – and need to investigate – more than they outline the specific lines our inquiries ought to follow.

Despite the rather glacial pace of change, however, the historical story remains one of development as well as stability, and the key issues raised by Damerow concern how we should understand this process of development. Here, as the whole line of discussion in this article has implied, the challenge is to grasp the connection between two different but, presumably, interconnected phenomena: the cognitive changes generated by a *change* in the medium of representation; and the cognitive changes we

might expect to emerge over time from the *use* of a given medium. Let us begin with the second issue.

I argued above against Damerow's suggestion that the key cognitive advance produced by the use of the clay tokens would have been the emergence of a concept "equivalent" to that of conservation of quantity. In doing so, however, I did not mean to call into question the most general point, that the use of the medium over a long period of time might well have generated some pressure for cognitive advance, particularly advance in capacity for abstraction. This strikes me as plausible. The question is what *kind* of cognitive advance was involved. Aside from the specific objections I raised against Damerow's formulation, I proposed – and would like to stress again here – a more general interpretive guideline: The kind of cognitive change I would expect us to discover within this stage is likely to involve, not the attainment of genuinely new concepts, but rather the refinement and crystallization of concept already present in an amorphous state. Or, to restate this point in more general terms, within a larger framework: Each numerical "stage," as we have seen, is defined by its specific system of numerical representation, which in turn is tied to a specific medium of representation. I would propose that, once a given stage is initiated by the invention of a new medium of representation, the development of cognitive structures *within* that stage is likely to be largely "continuous"; it would involve, to a considerable degree, bringing out the structural possibilities already inherent in the medium. However, *dis*continuity in cognitive structures, involving for example the attainment of genuinely new concepts, would require the impact of an external disruption, most crucially a change in the medium of representation (see Luria, 1977, for an analogous discussion at the individual level).

At the same time, the more "continuous" developments within a given stage would be required to prepare the way for the more dicontinuous breaks associated with the emergence of a new medium of representation. Let me suggest one way in which this might be the case with the Babylonian numerical systems.

In my tentative characterization of the clay-token stage, I concluded that it probably involved a gradual refinement and crystallization of the amorphous concept of quantity which was originally present. This tendency would go along, in a mutually-reinforcing way, with an effort to encompass a greater variety of situations under the different arithmetic

operations. This effort seems to have included the extension of the token-representation technique to more objects of economic life (e.g., Schmandt-Besserat, 1978). Thus far, what seems to be involved is largely the quantitative extension of an existing technique; however, there is some reason to think that it could have involved qualitative differentiation as well. I say this on the basis of the situation reported by Goody (1977) among the LoDagaa in northern Ghana. They used different procedures for counting different kinds of objects; in particular, they grouped different objects into sets of different sizes, and found it amusing when he attempted to count them laboriously one by one. Thus, it is possible that extensive use of the one-to-one correspondence technique in ancient Sumeria could also have given rise to a tendency to go beyond the "natural" unit of a given object and to group objects into multiple units. Nevertheless, such a movement would mean only a limited degree of abstraction, since grouping operations of this sort are not context- and content-independent. And a new medium of representation was required before these operations could be expressed in the representational system.

The emergence of the archaic texts involved an enormous advance in the complexity and flexibility of the system of numerical representation. One important change was the appearance of higher-order signs, which were, of course, absent from the clay-token system. The bases of the different higher-valued signs appear arbitrary to us at this stage of research. It is possible, however, that they express the different counting procedures which had begun to develop during the clay-token stage for dealing with different kinds of objects. This might explain the complicated base variations that we encounter between and within the different number sign systems. If so, this would accord with the general approach I outlined above for interpreting the cognitive structure of the first stage. If the notion of quantity was originally tied directly to concrete natural objects, so that the "natural" unit was the original "base" for the system, then the next level of generality would involve grouping the objects in ways which were still closely tied to contexts of practical activity. What would develop during the first stage would be an increasing cognitive need, so to speak, for a representational system which could embody such groupings. (This might, of course, involve not only a "learning" process induced by the use of the numerical system itself but also new requirements generated by changes in the economy and social

structure, etc.) However, a change in the medium of representation was required for the breakthrough to the new system. The new system was thus at an intermediate level of generality: more abstracted from the "natural" unit than the clay-token system; but not *entirely* free from it since it was still closely tied to the concrete objects and their use, though at a more inclusive level.

The new system was, however, not only more cognitively powerful but also potentially more dynamic – remembering, of course, that we are still talking in relative terms. In part, this was due to the shift, in the terminology of Aebli and Damerow, to a system of secondary representations, which coordinate action and cognition indirectly, thus allowing a considerable increase in abstraction. In addition, another crucial implication of the introduction of writing, and of the archaic-text system in particular, was that it was now possible to stabilize the records of quantities at different times and to represent the physical and economic events affecting them. I have already indicated why changes of this sort should have had an impact on arithmetic understanding. Furthermore, the possibility of representing and comparing the sequential end-states produced by quantitative changes should have made the *processes* involved in arithmetic operations more visible; and this, in turn, would at least have facilitated the effort to reflect on these operations as recurrent processes, and to formalize the rules implicit in them. The ability to formalize transformation rules and to consider them explicitly is, of course, the first step toward thinking about deliberately changing them. At the moment, however, arguments about the tendencies of cognitive development during the archaic-texts stage are necessarily speculative; the refinement of our own questions will depend on the information produced by the further examination of the texts themselves.

In closing, it is worth underlining Damerow's assertion that historical studies of cognitive structures are necessary for developmental psychology to evaluate its different theories. This is the case because developmental psychology attempts to explain change, which requires a perspective that embraces both individual and historical development. If we limit ourselves to studying individual development, we can never convincingly capture the way in which the endpoints of individual development are not universal but culturally shaped, a fact that historical studies bring immediately into proper focus. In this respect, Damerow's work extends Vygotsky's use of ethnopsychological studies and quite

successfully makes the development of cognitive structures its proper object of study. This framework highlights, by contrast, the limitations of work which restricts itself to studying only individual development. Arguments that focus on the individual's cognitive development need to be effectively integrated with those that deal with issues arising at the level of historical change. Damerow and his associates have made a noble effort to expand the horizons of psychological research and to demonstrate the indispensability of a comparative and historical approach in conducting psychological inquires.

Notes

1. Piaget borrows this term from biology, where it indicates the emergence of structure from the interaction between the organism and its environment, as opposed to the notion of an entirely preformed inherited structure.
2. My suggestions here grow out of a larger argument which is too complex to pursue in detail in this article. Theories of cognitive development often tend to assume, explicitly or implicitly, that the development of cognition follows a sort of building-block model, in which each block is added on to the one before. Thus, development seems to involve the gradual *accumulation* of different cognitive capacities. This theoretical imagery seems to me quite misleading; among other things, it obscures the fact that, as Piaget has consistently emphasized, a cognitive structure always involves an integrated *system* of cognitive relations. This suggests that, rather than emerging out of nowhere, a cognitive capacity is initially present in amorphous form and then has to be crystallized and refined through (learning and) development. But, though the logic of Piaget's position points beyond the building-block approach, he himself has not always or entirely shaken it off (and this holds even more true for many of his followers). This is, in part, because he stresses the necessarily systemic nature of a cognitive capacity once it has been *attained*; but he does not always treat the process of its attainment as involving a developing systemic structure. In this context, we should be more consistently Piagetian than Piaget. (I have been trying to work out this argument in a more comprehensive way, beginning with my dissertation; see, e.g., Nicolopoulou, 1984.) In dealing with the problem of cultural mediation, on the other hand, we need to go beyond Piaget.

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