We Have Met Technology and It Is Us

Michael Cole, University of California, San Diego
Jan Derry, Institute of Education, University of London

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The film, *2001,* provides a useful tool for thinking about the relationship between intelligence and technology. The opening scenes depict a pre-historic time when a troop of ape-like creatures inhabit an environment that is similar to contemporary images of the African savanna. The ape-like creatures forage side by side with pig-like animals in peaceful harmony, and both the apes and the pigs are prey to large members of the feline persuasion. The apes quarrel with each other and with other bands about access to a watering hole during which they jump up and down, making threatening sounds and gestures, but never directly kill their competitors. At night they huddle together beneath rock ledges, listening fearfully to the noises of dangerous predators.

One morning they awake to find a giant, black, steel rectangle lodged before them. It is clearly not a part of the natural world they have inhabited to that time. As the sun rises over this gigantic object (not unlike a huge domino made entirely of black Teflon of the kind you see at the bottom of a modern frying pan) one of the apes picks up the leg bone of an animal that has been killed in some previous encounter with a killer-cat, and the image of a pig dying appears on the screen – an anticipatory re-presentation in the dawning mind of the hungry ape. “Thought” turns into action. Now instead of peacefully grazing along side the pigs, the bleached femur of another animal serves as a means of killing then, and instead of jumping up and down and threatening competing bands of apes at a water hole, an alpha ape beats to death a marauding ape, and in an exaltation of victory, flings the bone-cum-weapon high into the air. The following shot is of a futuristic spaceship, controlled in large part by a computer, floating through space. Lest the meaning be misconstrued, the music accompanying the origin of tool use is from the portentous “Thus Spoke Zarathustra”, while the spaceship floats on the gossamer wings of the “Blue Danube Waltz,”.

We need not follow Stanley Kubrick's metaphor for technology and intelligence in further detail. Although his gloomy prognostications certainly fit the distopian views of many scholars who ponder the relation between human nature and technology, they are almost certainly deficient in terms of contemporary theories of hominization (Bogin 2001). It is sufficient for our purposes to note the widespread view that advances in human intelligence and the evolution of technology are intimately related.

Technology and Intelligence Re-viewed

In seeking to contribute to a discussion of the relationship between technology and intelligence we immediately confront the difficulty that both concepts are conceived of in widely divergent terms by contemporary social scientists and the public alike. As the bulk of the articles in this volume indicate, the term technology evokes thoughts of computers, telecommunications networks, and spaceships, the technologies which occupy 99.9% of the story in *2001*. This view of technology fits well notions of intelligence that Neisser, Sternberg, and others have referred to as "academic intelligence," e.g. the sorts of problem solving skills that result in constructing computer networks and exploring outer space. It is a form of intelligence associated with modern schooling in which problems are generally formulated by others, well-defined, have single correct answers, and single correct means of reaching those answers (Neisser 1976). As a rule, this form of intelligence is treated as a biological property of individuals.

In our view, technology and intelligence understood in this manner are likely to underestimate what we believe to be an intimate, even incestuous, relationship between the two terms. To begin with, our view of technology leads us backward in time to the early evolution of homo sapiens and such crude technologies as stone tools. This same view forces our attention to the fact that while tools may be considered constituents of technology, the concept of tool itself needs to be re-examined, and the concept of technology broadened. Our perspective derives in part from the idea of technology that comes down to us from the Greeks: "A discourse or treatise on art or arts; the scientific study of the practical or industrial arts." Examples of early uses of the term in English indicate its range quite well (e.g., "His technology consists of weaving, cutting canoes, making rude weapons, and in some places practicing a rude metallurgy" taken from an ethnographic description in the mid 19th century, Oxford English Dictionary). Essential to this broader notion of technology is that although tools are constituents of a technology, it is the way in which tools are deployed as part of a social practice that is crucial. As archaeologist, Michael Schiffer puts its, the study of technology "must focus on behavior and artifacts in the context of activities" (Schiffer, 1992, p. x) .

Our emphasis on technologies as forms of tool-mediated social practices also inclines us to adopt a broader notion of intelligence than that adopted in most contemporary theorizing on the subject. In its most general meaning, intelligence is better conceived of (following Piaget, 1960) as a process of adaptation to, and transformation of, the conditions of life. Important as it is to contemporary life, academic intelligence and the technological innovations it generates are not representative of life's adaptive endeavours (or as Binet and Simon noted, there is more to school than intelligence and more to life than school, Binet and Simon, 1916, p. 256). In support of this perspective, a number of scholars have pointed out that in a great many situations people must recognize or formulate problems which are of direct significance for their well being, are often poorly defined, require the acquisition of new information and allow multiple routes to solution (Neisser, 1976; Sternberg, Forsythe et al. 2000). Hence, a theory of technology and intelligence from our perspective must take into account not only the means, but the conditions, of thought and the thinker, all of which have generally evolved in close interaction with each other (Semaw, Rogers et al. 2003). A part must not be taken for the whole.

Artifacts: The Foundation Blocks of Technology

Thus far we hope to have induced the reader to consider the possibility that there is an intimate relationship between technology and human intelligence both conceived in unusually broad terms. Now we want to back up to consider the notion that technologies are constitutive of human nature in a deep sense that crosses the traditional lines between the mental and material, cognitive and non-cognitive, and biology and culture. We begin putting the whole together by examining more closely the most fundamental element of any technology, the artifact.

The Dual Nature of Artifacts

In our usage, an artifact is an aspect of the material world that has been modified over the history of its incorporation into goal directed human action. By virtue of the changes wrought in the processes of their creation and use, artifacts are *simultaneously ideal (conceptual) and material*. They are material in that they have been created by modifying physical material in the process of goal- directed human actions. They are ideal in that their material form has been shaped to fulfill the human intentions underpinning those earlier goals; these modified material forms exist in the present precisely because they successfully aided those human intentional goal-directed actions in the past, which is why they continue to be present for incorporation into human action.

The core of this idea was expressed by Dewey in the following terms: Tools and works of art, he wrote, “are simply prior natural things reshaped for the sake of entering effectively into some type of [human] behavior” (Dewey, 1917, p. 92).

The broad implications of the dual material-conceptual nature of artifacts were elaborated upon by the Russian philosopher, Evald Ilyenkov (1977, 1979), who based his approach on that of Marx and Hegel. As we have done, Ilyenkov and his followers emphasized that the form of an artifact is more than a purely physical form.

> Rather, in being created as an embodiment of purpose and incorporated into life activity in a certain way--being manufactured for a *reason* and put into *use* - the natural object acquires a significance. This significance is the "ideal form" of the object, a form that includes not a single atom of the tangible physical substance that possesses it (Bakhurst, 1990, p. 182).

What is important to us is that this view asserts the primal unity of the material and the symbolic in human cognition. This starting point is important because it provides a way of avoiding dualistic approaches to the relation between the mental and the material in human life and to overcome Cartesian dualism in theories of thinking, which locate mind entirely inside the human brain.[1]

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1 “ Dewey believed that “the tools and artifacts we call technological may be found on either side of what he argued was an extremely malleable and permeable membrane that separates the “internal” from the “external” with respect to the organism only in the loosest and most tentative senses (Hickman, 1990, p. 12).

Kinds of artifacts

While they share defining features, artifacts differ from each other in a number of ways and are not haphazardly incorporated into human activity.

Differentiating Artifacts by Levels

The late American philosopher, Marx Wartofsky, proposed that artifacts can be usefully distinguished by levels.

As examples of *primary artifacts* Wartofsky mentions axes, bowls, needles, clubs, etc. Their materiality is so manifest to us, that the ideality built into their form is all but invisible.

While all human productive activity involves the use of primary artifacts, the modes of action and goals that accompany their use are in turn constituents of *secondary artifacts* (social forms of organizing action, relations of kinship), which enable the preservation and transmission of modes of action using primary artifacts. Although couched in somewhat different language, there are a great many suggestions about secondary artifacts as constituents of human activity. For example, anthropologist Roy D’Andrade suggested the term cultural schemes to refer to units that mediate entire sets of conceptual-material artifacts. In D'Andrade's (1984, p. 93) terms:

> Typically such schemes portray simplified worlds, making the appropriateness of the terms that are based on them dependent on the degree to which these schemes fit the actual worlds of the objects being categorized. Such schemes portray not only the world of physical objects and events, but also more abstract worlds of social interaction, discourse, and even word meaning.

Psychologists such as Jerome Bruner (1990) and Katherine Nelson (1981) identify event schemas, embodied in narratives, as basic organizers of cognition. Referred to as scripts by Nelson, these generalized event schemes specify the people who participate in an event, the social roles that they play, the objects that are used during the event, the sequences of actions required, the goals to be attained, and so on. Nelson's account of scripted activity is similar in many ways to D'Andrade's suggestion that cultural schemas are the basic units of organized cognitive action.

Finally, Wartofsky identified special kinds of artifacts that he termed *tertiary artifacts.* These artifacts, he wrote, are ones in which "the forms of representation themselves come to constitute a 'world' (or 'worlds') of imaginative praxis," (Wartofsky, 1979, p. 207) allowing an arena for the playing out of broader intentions and affective needs. Although each kind of artifact may be considered independently of others, each, with its own mixtures of materiality and ideality arises from, and acts back on, the other. It is in this way that human beings bootstrap the means of their own cognition.

One of Wartofsky's main point is that 'environment' is not a neutral term because it is changed by organisms and populations of organisms and in the case of humans that transformation results from activity that includes artifacts. 'Nature becomes transformed, not only in the direct practical way of becoming cultivated, or shaped into objects of use in the embodied artifacts we call tools…it becomes transformed as an object or arena of action, so that the forest or river is itself an 'artifact' in this ramified sense.' (Wartofsky, 1979, p. 207) In the same sense Ilyenkov presents the idea of nature as *idealized.* Meaning is embodied in the environment in which individuals are active and move us toward a radical alternative to the dualism endemic in conceptualizations of human cognitive capacity in which human physiology is realized only in an environment rich with the means of cognition. From this alternative perspective, intelligent activity arises as humans are able to orient themselves in the idealized environment that is the expression of nature in its human aspect. At each 'level' of activity more is entailed than is initially the object of an activity.

Differentiating Artifacts by Function: Cognitive "versus" non-Cognitive Artifacts?

Following the path laid out by Wartofsky we are encouraged to differentiate artifacts by their levels, from those that mediate specific human actions to modes of action requiring the deployment and sequencing of many "primary" artifacts, to imaginative alternative worlds, to "anything which human beings create by the transformation of nature and of themselves: thus also language, forms of social organization and interaction, techniques of production, skills.' (Wartofsky, 1979, p. xiii) Clearly, the exercise of intelligence is implicated in all forms of artifact-mediated human interaction.

Nor is this a uniquely modern insight. Even those who have focused rather narrowly on technology as primary artifacts, tools that amplify particular forms of human action, are likely to make the further claim that tools change not only actions directed outward on the world, but change the process of thought itself. For example, in the 17th Century, Sir Francis Bacon, arguably one of the most important progenitors of contemporary science, declared:

> *nec manus, nisi intellectus, sibi permissus, mutlam valent: instrumentis et auxilibus res perfictur.* ["The unassisted hand and understanding left to itself possess but little power. Effects are produced by the means of instruments and aids, which the understanding requires no less than the hand; and as instruments either promote or regulate the motion of the hand, so those that are applied to the mind prompt or protect the understanding."] (Bacon, 1620, p. 345)

In the early 20th century, the French philosopher, Henri Bergson, spoke for many in this tradition when he wrote that:

> If we could rid ourselves of all pride, if, to define our species, we kept strictly to what the historic and prehistoric periods show us to be the constant characteristic of man and of intelligence, we should say not *Homo Sapiens* but *Homo Faber*. In short, *intelligence, considered in what seems to be its original feature, is the faculty of manufacturing artificial objects, especially tools for making tools, and of indefinitely varying the manufacture* (Bergson, 1911/1983, p. 139).

Strikingly absent in these early statements of how human intelligence is linked to mediation of human action through tools, although present in Wartofsky's writings, is the idea that there is a category of artifacts that are expressly designed to influence some aspect of human thought. Lev Vygotsky referred to this category of artifacts as *psychological tools*. As examples of psychological tools he listed all kinds of symbolic cultural artifacts including not only linguistic signs and symbols, but counting schemes, mnemonic devices, diagrams, maps, all of which enable human beings to master psychological functions like memory, perception, and attention "from the outside." (Vygotsky, 1981)

In the early 1990's Donald Norman (who had not, so far as we know, encountered the ideas of Ilyenkov, Vygotsky or Wartofsky) began to promote the idea of *cognitive artifacts* (Norman, 1991, 1993). Citing the general argument we have made that the creation and use of artifacts is central to human nature, Norman defined cognitive artifacts as "an artificial device designed to maintain, display, or operate upon information in order to serve a representational function" (Norman, 1991, p. 17).
The idea of a representation is not defined precisely, but the idea is clear enough from both the remarks Norman makes about representations and the examples he provides. Pooling this information (Norman, 1993, p. 49-51 and 1991, p. 25ff) we can say that
A representation is as a set of symbols that substitutes for the real event.

- ⇒ Once we have ideas represented by representations, the physical world is no longer relevant.
- ⇒ Representations are abstractions so good representations are those which abstract the essential elements of the event
- ⇒ The critical trick is to get the abstractions right, to represent the important aspects and not the unimportant. This allows everyone to concentrate upon the essentials without distraction from irrelevancies.
- ⇒ Representations are important because they allow us to work with events and things absent in space and time, or for that matter, events and things that never existed – imaginary objects and concepts.
- ⇒ A person is a system with an active, internal representation.

At many points in his discussion, Norman makes clear that cognitive artifacts are *extrinsic* to human thought, external complements to naturally occurring internal representations. First, he states this view quite directly as a general premise for his treatment of artifacts, asserting that he wants to "emphasize the information-processing role played by physical artifacts upon the cognition of the individual" (1991, p. 18).

Norman elaborates on the separation between cognitive artifacts and “natural” human thought by offering a contrast between two views of artifacts, a “system” view and a “personal” view. (See Figures 1 and 2 below):

Insert Figures 1 and 2 illustrating Norman’s distinction between a system view and a personal view of artifacts

To use an example that Norman himself proposes, lets assume that the artifact in question is written language, a list of things that the person seeks to remember – say, an airplane pilot reading a checklist in preparation for a flight. From a system view, he argues, it appears that one is dealing with a total structure inclusive of person, artifact and task. The artifact appears intrinsic to the act of remembering. But from the perspective of the individual person, the artifact has simply changed the task. In fact, reading the list has, itself, become a task. Norman summarizes the situation as follows:

> Every artifact has both a system and a personal point of view, and they are often very different in appearance. From the system view, the artifact appears to expand some functional capacity of the task performer. From the personal point of view, the artifact has replaced the original task with a different task, one that may have radically different cognitive requirements and use radically different cognitive capacities than the original task (1991, p. 22).

At first blush, it seems difficult to avoid the conclusion that what Norman refers to as the “personal point of view” is simply a confusion. For the airplane pilot, a written list mediates action. The goal of the action, with or without the list, is to have a safe flight. However, Norman is here drawing upon a long tradition in psychology that defines a cognitive task as a goal and the constraints on achieving it. From this perspective, any change in the means by which the goal is achieved ipso facto change the nature of the task.

We can see a certain heuristic value to making this strong distinction between internal and external representations and the implied distinction between cognitive and non-cognitive artifacts. Artifacts that partake of the cognitive, in this view, should be studied in terms of the kinds of representations they can encompass. A voice recognition device, for example, would be an excellent example of a cognitive artifact because of the enormous amount of representational information it contains. The analyst’s task becomes one of figuring out the most natural interface between the input-output capacities of the device and the (internal) representational state of the user. Or, as Norman puts it:

> We can conceptualize the artifact and its interface in this way. A person is a system with an active, internal representation. For an artifact to be usable, the surface representation must correspond to something that is interpretable by the person, and the operations required to modify the information within the artifact must be performable by the user. The interface serves to transform the properties of the artifact's representational system to those that match the properties of the person (1991, p. 22).

When all is said and done, Norman's use of the notion of cognitive artifact enables him to argue that cognitive artifacts "serve human cognition." The idea that all artifacts, like all human action (including the kind of action we refer to as "thinking"), are at once ideal and material is lost. As a consequence, Norman speaks of cognition being distributed among humans by virtue of shared action involving artifacts, but cannot conceive of the possibility that the sharing is a mediated interaction, always involving other people and the artifact-saturated environment.

Intriguingly, Wartofsky also used the term, cognitive artifact, commenting at one point that "we create cognitive artifacts which not only go beyond the biologically evolved and genetically inherited modes of perceptual and cognitive activity, but which radically alter the very nature of learning and which demarcate human knowledge from animal intelligence" (Wartofsky, 1979, p. xv) But for Wartofsky, cognitive artifacts such as representations are not *what* we perceive. Rather, they are *the means by which* we perceive real objects. This distinction, though apparently trivial, is key to appreciating the active and practical nature as well as the external (socio) genesis of our cognitive capacities (about which we will have more to say below). Wartofsky speaks of our faculty of perception as the result of activity rather than as a capacity: "I take perception itself to be a mode of outward action or praxis. In this sense, it is perceptual activity *in* the world, and *of* a world as it is transformed by such activity" (Wartofsky 1979, p. 194). But also coupled to the idea of cognition as activity is a conception of knowledge that rejects a 'given' upon which our 'theory-dependent observation' selects features of nature. Rather what is 'there' or 'given' in nature is already a product of material activity. The form of production and reproduction of the human species takes place with the use of tools/artifacts in the sense that human activity is goal-oriented transforming the environment to fit our purposes rather than merely inhabiting what is made available at any point by nature.

The Functional Structure of Artifact-mediated Action

Regardless of the properties they attribute to artifacts, those who claim a strong link between human technologies and human intelligence is that tools/technologies mediate human action. In the Russian cultural-historical tradition upon which we draw, the relation of artifacts to human action is likely to be depicted as a triangle representing the structural relation of the individual to environment that arises *pari parsu* with artifact use (see Figure 1) (Vygotsky, 1929, 1978). Simplifying this view for purposes of explication, we can say that

[Insert Figure1 here]

the functions termed "natural" or "unmediated") functions are those along the base of the triangle; the "cultural" ("mediated") functions are those where the relation between subject and environment (subject and object, response and stimulus, etc.) are linked through the vertex of the triangle (artifacts).

There is some temptation when viewing this triangle to think that when artifacts are incorporated into human action, thought follows a path through the top line of the triangle, e.g., that it "runs through" the mediator. However, the emergence of mediated action does not mean that the mediated path *replaces* the natural one just as the appearance of culture in phylogeny does not replace phylogeny by culture. One does not cease to stand on the ground and look at the tree when one picks up an axe to chop the tree down; rather, the incorporation of tools into the activity creates a new structural relation in which the cultural (mediated) and natural (unmediated) routes operate synergistically; through active attempts to appropriate their surroundings to their own goals, people incorporate auxiliary means (including, very significantly) other people, into their actions, giving rise to the distinctive, triadic relationship of subject-medium-object.

Even this basic notion that human thought is the emergent consequence of intermingling of "direct/ natural/phylogenetic " and "indirect/cultural/historical" aspects of experience is sufficient to bring to the fore the special quality of human thought referred to as the duality of human consciousness. As the American anthropologist, Leslie White, wrote[2]:

An axe has a subjective component; it would be meaningless without a concept and an attitude. On the other hand, a concept or attitude would be meaningless without overt expression, in behavior or speech (which is a form of behavior). Every cultural element, every cultural trait, therefore, has a subjective and an objective aspect (1959, p. 236).

A great deal more can be said about this basic conception of artifact-mediated human action and the peculiar form of consciousness to which it gives rise (Cole, 1996). However, artifacts and artifact-mediated individual human action are only a *starting* point for developing the needed conceptual tools for thinking about technology and intelligence. Neither artifacts nor actions exist in isolation. Rather, they are interwoven with each other and the social worlds of the human beings they mediate to form vast networks of interconnections that is known as human culture (Ellul 1980; Latour 1993).

From Artifacts to Culture

Implicit in our discussion thus far, and stated directly by White in the passage quoted above, is an implied, but unexplicated claim that there is a close relation between the nature of artifacts and the nature of culture. It is time to make that linkage clear.

In its most general sense, the term "culture" is used to refer to the socially inherited body of past human accomplishments that serves as the resources for the current life of a social group ordinarily thought of as the inhabitants of a country or region (D'Andrade, 1996). In trying to specify more carefully the notion of culture-as-social inheritance, anthropologists have historically tended to employ the same dichotomy to culture that we have sought to supersede with respect to the concept of artifact. As Roy D’Andrade has noted, during the first half of this century, the notion of culture as something “superorganic” and material dominated anthropological thinking, but as a consequence of the “cognitive revolution” in the social sciences, the pendulum shifted, so that for several

2 Richard Barrett (1989) provides a useful discussion of White’s symbolic/ mediational views in relation to his better-known views concerning materialist evolutionism.

decades, a “culture-as-knowledge” view has reigned. This latter view is most closely associated with the work of Ward Goodenough, for whom culture consists of "what one needs to know to participate acceptably as a member in a society's affairs" (Goodenough 1994, p. 265). This knowledge is acquired through learning, and consequently is a mental phenomenon. As Goodenough (1994, p. 50) put it,

> Material objects people create are not in and of themselves things they learn... What they learn are the necessary percepts, concepts, recipes, and skill-- the things they need to know in order to make things that will meet the standards of their fellows. From this perspective, culture has little to do with artifacts, which are considered a part of material culture, while the real stuff of culture is profoundly subjective. It is in people's minds, the mental products of the social heritage.

However, just as we and other psychologists are seeking to transcend this “ideal versus material culture” dichotomy, so too have anthropologists. For example, in an oft-quoted passage Clifford Geertz (1973, p. 45) wrote that his view of culture begins with the assumption that,

> human thought is basically both social and public-- that its natural habitat is the house yard, the market place, and the town square. Thinking consists not of "happenings in the head" (though happenings there and elsewhere are necessary for it to occur) but of trafficking in ... significant symbols -- words for the most part but also gestures, drawings, musical sounds, mechanical devices like clocks.

Geertz, coming at the problem from a quite different direction than we have taken, provides an escape from the ideal-material dichotomy with respect to culture that dovetails perfectly with the idea that human beings live in an environment transformed by the artifacts of prior generations. The basic function of these artifacts is to coordinate human beings with the physical world and each other; in the aggregate, culture is then seen as the species-specific *medium* of human development. D'Andrade (1986, p. 22) made this point when he said that "Material culture—tables and chairs, buildings and cities—is the reification of human ideas in a solid medium". It is as a consequence of the dual conceptual-material nature of the systems of artifacts that are the cultural medium of their existence, human beings live in a double world, simultaneously natural and artificial.

Geertz's reference to the house yard, the market place and the town square remind us that is insufficient to think of artifacts as all of a piece or haphazardly strewn around the environment. Rather, they are better considered as constituents of cultural practices, each of which aggregates artifacts into different kinds of technologies for dealing with the world at hand.

Arranging for the Acquisition of Technologies

The views of tool use as both amplifier of human action and transformative of human mind and that technology, taken as a whole, constitutes the special environment of human life, take on even broader significance when they are combined with a theory of human development. Such a theory assumes that cognitive development depends crucially on the ways in which adults arrange that environment so that as children interact with more mature members of the social group, they simultaneously acquire the cultural toolkit (ensemble of technologies) that are the group's social inheritance. This idea, which can be traced back to Janet (See Valsiner and van der Veer 2000), has received its most influential formulation in what L.S. Vygotsky referred to as "the general law of cultural development":

> Any function in children's cultural development appears twice, or on two planes. First it appears on the social plane and then on the psychological plane. First it appears between people as an interpsychological category and then within the individual child as an intra-psychological category... but it goes without saying that internalization transforms the process itself and changes its structure and function. Social relations or relations among people genetically underlie all higher functions and their relationships (Vygotsky, 1981, p.163).

The idea that inter-psychological processes (transactions between people) precede intra-psychological processes (complex mental processes in the child's mind) appears counterintuitive when mind is understood as an inbuilt individual capacity that matures on an invariant time schedule. However, the view that inter-psychological processes precede intra-psychological processes is a natural conclusion if one starts from the assumption that older members of the community are bearers of the intellectual tool kit of the social group that is essential both to the group's survival and the knowledge essential to the development of mind, so that transactions between adults and children are the means for the individual's appropriation of the knowledge essential to the development of mind. This latter view, which we adopt in this chapter, can be summarized by saying that all means of social behaviour (technologies) are social in their essence (and in the dynamics of their origin and change) so that the structure and development of human intelligence emerges through culturally mediated, historically developing, practical activity. Furthermore, this statement applies equally to the phylogeny and ontogeny of human intelligence, broadly understood.

The Phylogenetic Interweaving of Artifacts, Culture, and the Human Brain

Even if the reader accepts our claim about the priority of the social group in the development of specifically human psychological abilities, the idea that the human phylogeny also involves "culturally mediated, historically developing, practical activity" may seem a bit odd.

However, because artifacts aggregated into technologies (for killing and cutting up large animals, for food, for transforming their skin into clothing and sources of shelter, etc.) and have been present for perhaps 2 ½ million years prior to the emergence of *homo sapiens*, it is not appropriate to focus on technology and intelligence without including human biological as well as technological/cultural evolution. The human brain and body co-evolved over a long period of time with our species' increasingly complex cultural environment (Quartz and Sejnowski 2002; Plotkin 2003; Semaw, Rogers et al. 2003). When Clifford Geertz (1973) examined the mounting evidence that the human body, and most especially the human brain, underwent a long co-evolution with the basic ability to create and use artifacts he was led to conclude that,

> man's nervous system does not merely enable him to acquire culture, it positively demands that he do so if it is going to function at all. Rather than culture acting only to supplement, develop, and extend organically based capacities logically and genetically prior to it, it would seem to be ingredient to those capacities themselves. A cultureless human being would probably turn out to be not an

> intrinsically talented, though unfulfilled ape, but a wholly mindless and consequently unworkable monstrosity. (p. 68)

Despite 30 years of intensive research on his issue and all of the controversies one would expect given the many remaining gaps in the evolutionary record, Geertz's main point appears secure. The human brain of modern homo sapiens is several times larger and more complex than the brain of *homo habilus,* among whom the first rudimentary tools were discovered. Moreover, that growth took place in an environment that was increasingly influenced by the products of (proto) human activity. In short, the human brain evolved in an environment increasingly modified by human culture, such that interaction through culture/technology became an essential design feature of *both* human biology *and* the human life world. As neuroscientists Steven Quartz and Terrence Sejnowski summarize matters, "culture plays a central role in the development of the prefrontal cortex.... [so that] "Culture, then, contains part of the developmental program that works with genes to build the brain that underlies who you are" (2002). They emphasize, especially, the fact that the prefrontal cortex, which is the latest brain structure to develop in both phylogeny and ontogeny, and which is central to planning functions and complex social interaction, depends crucially on culture for its development.

Quartz and Sejnowski develop a broad view of culture as "groupwide practices that are passed down from one generation to the next" (p. 82) and note that traces of culture can be found in our near phylogenetic neighbours. Symptomatically, they adopt a corresponding broad view of intelligence that encompasses both its academic and everyday features, commenting that "Not only is intelligence a complex strand of social, emotional, intellectual, and motivational brain systems, but the central role of culture in our mental life reveals that intelligence isn't just inside the head. (p. 233)"

Quartz and Sejnowski mention neither the notions of technology nor of tool in their fascinating presentation of what they refer to as "cultural biology." But they do make a comment that provides a natural and productive bridge between their approach and that which we adopt when they comment that "The artifacts of human culture are unlike anything ever seen in the three-billion-year history of life on earth (p. 67)."

In order to make progress in fleshing out these ideas, we believe it is important to note that the invocation of culture with respect to near-phylogenetic cousins and progenitors refers to practices with no reference to artifacts, while it is the artifacts of human culture that appear to the locus of inter-phylogenetic discontinuity.

In this connection, the example of archeologists which was used by philosophers in the inter-war period is pertinent. In understanding objects such as a lost city or particular artifacts they pointed out – the knowledge of its natural material was of limited use. What was critical was to know the reasons and purpose behind it. Foster quotes an archeologist who wrote "We found cuttings in the rocks which puzzled us for a long time till [we discovered] they were wine presses" and he comments; "This discovery was not a detection by any of the sense of sensible qualities which had hitherto [not been] known, it was the discovery of the purpose for which the cuttings had been made" (Foster, 1934; See also Schiffer, 1992). Drawing upon a large body of theory and research from that branch of cultural psychology referred to as cultural-historical-activity theory, which allows us to link artifacts and practices to the notion of technology, we believe we can establish the complementarity of Quartz and Sejnowski's approach stemming from their deep knowledge of neuroscience with an approach that begins with scholarship stemming from the study of human development in its cultural and historical contexts.

This long-term, phylogenetic perspective is also important to keep in mind when considering the ontogeny of children, for it reminds us that causal influences do not run unidirectionally from biology to culture. Rather, human beings are hybrids of phylogenetic, cultural-historical, and ontogenetic sources. Activity-dependent influences, no less than activity-expectant processes, shape the development of the human brain (Cole, 1996).

Nature Through Nurture; Working through an example

The position we have been developing in this chapter strongly urges us to keep in mind the bi-directional influences between culture and biology which no longer appear as polar opposites, but as intertwined aspects of human nature. We end our discussion using a phrase which is the title of a recent book by Henry Plotkin, well known for his writings on Darwinism (Plotkin 2003). Like Quartz and Sejnowski, as well as ourselves, Plotkin argues for a view of culture and the social origins of higher human psychological functions based upon the ideas of Vygotsky and our view of the duality of artifacts. But, like many who are discovering this mode of thinking about technology and human nature, Plotkin's discussion remains at a relatively general level which needs filling in with concrete, well worked out examples that range across phylogeny, cultural history, ontogeny, and microgenesis. In the spirit of this effort, we provide one such example, for which there is more than the usual amount of evidence concerning brain-technology-ontogeny relations, although there is still much to be worked out.

The case of the use of the abacus by Japanese school children and adults provides an illustration of how thoroughly the historical processes involved in the development of tool use becomes incorporated into a culture-specific technology while simultaneously becoming a part of human nature.

With respect to phylogeny, the most that we can say is that there is currently a good deal of evidence for at least rudimentary arithmetic abilities in non-human primates (Boysen and Hallberg 2000), but there is no known case of the use of artifacts in this process, let alone an artifact as complex as an abacus. The abacus, which traces its origins back several thousand years to Sumer in the fertile crescent, was introduced into Japan from China where it appears to come into used in the 14^{th} century, AD. For many centuries the Japanese have used the abacus (referred to as *sokoban* in Japanese) as a basic tool for mathematical calculations (Ifrah 2000).

Since its introduction, this tool has spread "outward" to form around itself a set of social practices that render it a technology while simultaneously burrowing "inward" to become a mental tool with a specific localization in the brain for those who become expert in its use. Giyoo Hatano and his colleagues, who have been leaders in studying the psychological consequences of this technology, report that use of the abacus is introduced into the elementary school curriculum around the third grade, following the introduction of paper and pencil algorithmic techniques in the first and second grade (Hatano 1997). But involvement in using the abacus is not restricted to the formal school curriculum. Rather, there are special afterschool schools (juku) that specialize in teaching use of the abacus and especially the skill of making calculations using a "mental abacus," an image of the real thing, which allow experts to carry out very large calculations "in their heads" (although movements of their fingers often accompany such calculations). There are also clubs that form to permit children and adults, who often practice using it two or more hours a day, engage in tournaments, much in the spirit of American intercollegiate sports. There is a national organization that has created a standardized examination with 10 grades of mastery. In 1971 more than 2 million Japanese had taken this examination. Considerable research indicates that achieving high levels of skill in the use of the mental abacus are associated with improved mathematical performance that involves much more than bare calculation (summarized in Hatano, 1997). Moreover, current research has begun to direct itself toward understanding the brain basis of high levels of abacus training (Hanakawa et al., 2003 ; Tanaka, Michimata et al., 2002). Whether tested for digit memory or mental arithmetic, fmri recordings of abacus experts engaged in such tasks show right hemisphere activation of the parietal area and other structures related to spatial processing. The fmri activity in Non-experts engaged in such tasks is in the left hemisphere, including Broca’s area, indicating that they are solving the task by language-mediated, temporally sequential processing. When compared engaged in verbal tasks, experts and non-experts display the same forms of left-hemisphere-dominated fmri activity. Although a great deal more research is needed, the case of the abacus illustrates the way in which psychological tools, incorporated into cultural practices, both constitute those practices as technologies and that this experience reacts back on the human brain. Nurture becomes nature.

This example also points to the kind of interdisciplinary work that will be needed to carry the study of technology and human nature/ intelligence forward in the years to come. What is called for are interdisciplinary teams, ideally, but not necessarily, located in the same institutions, who can help each other span the enormous range of expertises necessary to encompass phylogenetic, cultural-historical, ontogenetic, and microgenetic processes (including online brain imaging) together in single research efforts. It’s not an easy goal to achieve. But at least we now have a better grip on what the development of more powerful theorizing about technology and human nature requires.

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