

DIGITAL COMMUNICATION, MATERIAL INTELLIGENCES AND NEW INFRASTRUCTURES OF KNOWLEDGE/ACTION

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1. Words like knives

Words are sharp like the blade of a knife. They wear down according to the hardness of what is to be cut. In the same way as a table knife cannot cut diamonds, a simple penknife will not even make a notch in noble metal.

The same occurs in the world of symbols and concepts. Not all tool sets are equipped to tackle effectively the toughest and most complex notions. This explains why time runs out while the notions and entities that we most keenly pursue remain intact, and while the theories and conceptual apparatuses that attempt to explain/exploit them inevitably get blunt and rusty.

The scene is familiar and anxiety grows as concepts and problems become increasingly complex or more urgent and pressing. The situation explodes when we set out to address digital communication and attempt to understand its implications and the reasons why we can and should pay serious attention to the issue involving an epochal transmutation brought about by the onset of mass connectivity and, most importantly, of an unprecedented systematic and collaborative increase of intelligence.

2. Computers, communication and literacy

We cannot envision digital communication and literacy becoming widespread unless we admit that literacy is inseparable from the process of hominization.¹

The fact that our ordinary lives are permeated by our literate (predigital) selves is obvious when we tackle any daily routine involving our cognitive operations. We get out of bed and read (listen and scan) the newspapers and news. Before we even have time to decode a single letter we are invaded by images and signs overflowing with text. We cannot even imagine the possibility of leading a barely decent life in a society that has made texts and commented images the ABC of our being-in-the-world.

For the past fifteen years, our daily contact with information has increased and multiplied as we feed on a daily diet of e-mails and text messages, web pages and the more recent incorporation of weblogs and social sites. This daily task is time-consuming and has drastically changed our notion of social relations, taking us beyond the bounds of time and space. The distinctive feature of these new means of communication is that they circulate via telephone lines and cables (copper, coaxial or optic fiber pairs).

No less important is the widespread requirement of literacy at work. If, as Fernando Flores says, we are paid to talk, it has become increasingly evident that we are paid to think, to establish distinctions and, more importantly, to read and write, but, above all, to talk through these lines.

All the activities associated with science and technology and, more specifically, with the industry of knowledge (ranging from entertainment to high culture and from the most elementary infrastructures to highly conspicuous forms of cognitive consumption) are associated with our literate selves. In other words, our capacity to inscribe and recognize signs, our conversational skills, and our use of networks (physical, social, socio-technical).

Lastly, literacy is central when we are dealing with transmission (in the sense that Régis Debray gives to the processes involved in maintaining cultural continuity). In other words, literacy is the quintessence of all educational processes (in their broadest sense, both formal and informal, hierarchical and ordinary, general and specific, documentary and introspective), the underlying framework. If a person does not master reading skills and lacks basic mathematical literacy, he/she will be unable to grasp the contents of texts referring to the history of science or mathematics. Therefore, to give up learning or be denied literacy marginalizes us as citizens, isolates us as members of the community and condemns us to a second rate existence.

However, literacy is closely associated with different technologies of knowledge, a progressive expansion of our expressive capabilities and a growing communion between our instruments and

our cognitive capacities. Literacy, therefore, is achieved by degrees and involves a succession of rising steps. As new protocols emerge (social practices associated with new tools), literacy branches out, acquires new meanings and sets in motion increasingly complex and overdetermined remedial processes that require traditional literacy (math, language) that must be reinforced by mediatic and computational literacy in an increasingly intense and widespread reticulate society.

Though it is true that the commercial uses of machines determine their value in light of the possibilities of socialization they afford to vast numbers of people, for the most part they are operated by users who are digital immigrants. Though the appropriation of these machines for aesthetic purposes is relatively recent, there exist at present several generations of netartists, most of whom were formed within traditional socialization environments.²

This explains the interest in imagining what kind of aesthetic and cultural production will be developed by digital natives (children born after the 1980s) whose work is beginning to appear on the network.

3. Literacy involves much more than the devices that contribute to make it possible

The use of personal computers (domestic, commercial and educational) began to spread in the early 1980s. In the initial stages, the number of personal computers in homes and schools was very limited, but thanks to several combined laws designed to promote the widespread use of these innovations (Moore, Metcalf, Reid), their expansion grew exponentially.

In the U.S., in 1995, there was one computer for every 10 children, quite distant from the 1:3 or 1:2 ratio required to ensure a thorough socialization based on computational literacy. Even in this case, there is room for doubt as to whether the mere act of cramming schools with computers will guarantee, by itself, that something outstanding and noteworthy will occur in the world of history and literacy or in the field of art.

What is the best thing that can happen in terms of education thanks to the intensive use of computers linked to a network? What would learning be like in a world in which machines are used appropriately? How can we be sure that our vision will be sustainable over time and, most importantly, that it will be effectively received by the children? What software should be created to achieve this objective and what methodology should be developed to ensure that things are done correctly?

Online computers may become the technical foundations of a new and improved literacy which in many cases will operate in the same manner as the current written literacy. It may be assumed that this kind of literacy will achieve a widespread penetration and influence comparable to the massive access to literacy afforded by the creation of the printing press.

All this revolves around our notion of computational literacy. Traditionally (there was a time when we ourselves, at the lowest end of the continuum, supported this vision), there was a belief that the mere act of turning on a computer, mastering the rudiments of office or home automation and having a vague idea of how to surf on the Internet sufficed to open the doors to the new world of virtual wonders and terrors. Serious mistake. Persisting in this attitude and remaining content was tantamount to confusing a child's first faltering words with poetical expression and believing that spelling amounted, by itself, to the conquest of meaning.

Computational literacy will be infrastructural or will be nothing at all, and its implications—assuming that our intuitions and projects are directed at achieving a specific aim—must have the same impact in terms of socialization and cognitive capabilities in alternative worlds as that brought about by handwriting, the alphabet and the printing press, in addition to perspective, the camera obscura and the countless devices employed in pictorial representation in their respective beginnings, but all of them combined and strengthened.

It is really outrageous to assume that computational literacy is limited to the faltering use of computers by adults or their indolent use by children and digital natives and, consequently, to assume that the use of these machines is limited to formal work or educational environments.

Fortunately, the interventions produced by Mariano Sardón³ throughout his career are following the precise path (from and towards aesthetics) that we are outlining here.

4. The proliferation of material intelligences

Perhaps the first step towards discovering the nugget concealed in so much rust consists in *substituting the idea of literacy with that of material intelligence*. Material intelligence sums up and adds to the spontaneous development (because it is really permeated by the uninterrupted culture of generations) of our purely intellectual work. This intellectual display takes place exclusively in the presence of material mediators ranging from paper and pencil, abacuses and double-entry tables to computers themselves in the role of multipurpose simulators.

Material intelligence does not equate with artificial intelligence nor does it conjure up fantasies of more-than-human robots (though this is another chapter worth exploring at some point and, hopefully, within the context of a future exhibition). Material intelligence is natural intelligence plus mechanical extensions.

All forms of literacy (both those we have already acquired as well as those we are striving to incorporate) stem from a threefold acquisition. The first is material. No literacy is possible without material inscriptions outside one's own mind (enthusiastically described by William Shakespeare in his unforgettable Sonnet CVIII: "*What's in the brain that ink may character...*")

It is thanks to these external forms that we are able to make our ideas portable. Reading a map, checking a bank account, planning our itinerary, inquiring about prices online are different expressions of this power. Moreover (and here lies the great value of sketches, designs and mock-ups but, above all, of computer models or installations like *Peristáltica* or *Máquinas de escribir*), we can imagine combined and alternative (both real and virtual) futures and make them behave differently thanks to the existence of these cognitive exoskeletons. This is what net.art and electronic art are taking to their last (or first?) consequences.

The weight of the material foundations of literacy is constantly neglected and, aside from Bruno Latour, only a small number of thinkers have given the topic serious consideration and have been able to draw conclusions from past mediamorphoses with interesting and risky implications for the future.⁴

These forms of material knowledge are highly encoded, are structured in distinct subsets and interrelate with one another allowing some things and barring others. Written language, by far the best known of all these subsystems, is made up of primary particles, unfolds at different levels and affords us the whole gamut of communicational experiences ranging from the most commonplace transcription of the thing itself to highly complex constructions (paradoxes, multiple descriptions, polycasual statements) that we still find hard to decode and reproduce mechanically.

Other notational and representational subsystems have a completely different character and functionality. Arithmetic, for instance, is a poor vehicle for writing poetry or philosophy but, where applicable, it enables us to think with precision and conciseness. Entire fields of knowledge (engineering, sciences, technology) would be unthinkable if they were deprived of the possibility of understanding the relationships between the basic pillars of nature that is afforded by mathematics, a science that has unfortunately become restricted to the realm of experts and geniuses.

It follows that neoliteracy in all its forms requires that mathematics be freed from its confinement and, most importantly, it demands a reappropriation of concrete mathematics (as proposed by Maurice Frechet in 1955) to be applied to everyday affairs.

5. Technological dependence and design of literacy

The two key features of the materiality of literacy are its technological dependence and the fact that it is designed. The possibility of providing literacy on a massive scale from the Renaissance to our times would have been unimaginable without a drastic drop in the cost of paper and pencils that are both easy to use and portable.

One of the most convincing promises of computer technology is precisely (as predicted a decade ago by Robert K. Logan, 1996) the dazzling range of inscription forms (spreadsheets, electronically processed images, hypertext, etc.), of reactive and interactive patterns (game interfaces real-time reflex interaction, contemplative browsing of a visually based interactive mystery story), of storage and transmission modes (CDs to worldwide networking), and of autonomous actions (simulations, calculation).

It is the vastness of new resources and of possibilities of manipulating the symbols inherent to them that convinces us of the irreversibility of this new form of incipient literacy. Moreover, *electronic art has a key role to play as a tool for these new forms of literacy.*

It is not a matter of praising the magic of computing (as some techno-mystics or techno-gnostics do), but rather of revising, in the previous revolution, the specific gravity (generally ignored) of material factors in the development of conscience and cognition. In this parallel reading, the focus is on the catalytic power of these inscriptions and the multidimensional visualization format.

Moreover, all these inscription forms (from the number zero to the *pull-down* menus) were invented either deliberately or by chance, individually or collectively, driven by a constant selective social pressure. It is to be hoped that better and deeper changes will stem from the latest studies in the psychology of inventions, the theory of creativity and user-centered design—in particular, the pioneering and well-founded works of Donald Norman, Henry Petrowski, Edward Tenner and many others. These new concepts have succeeded in overcoming dichotomies (real/virtual, discourse/technology, science/art) when embodied in the installations created by John Maeda, Jenny Holzer, Brenda Laurel, Agnès Hegedus, Stelarc and Igor Stromajer (Popper, 2007).

6. Biology of inscriptions

The second pillar of literacy is cognitive or mental. What we do with the inscriptions will depend on our biological makeup, our knowledge of physics and our computing skills. Nobody (other than an evolutionary misfit) can see and remember a thousand items presented in a flash or draw certain kinds of inferences as quickly as a computer.

Our ability to talk and comprehend oral language is partly physiologically specific (it took centuries to understand why chimpanzees cannot speak... because they have no vocal chords), and without this physical equipment, written literacy would also probably be impossible.

If we are so convinced that computational literacy will leave such an indelible imprint in the evolution of literacy, it is because computers will release innate human capacities regarding spatial recognition and conversational interactivity that we rarely see in normal practice, let alone in the classroom. To a certain extent, Sardón's work deals with this release of human capabilities.

Computational inscription systems should therefore build on strengths in human mental capacities, and they must also recognize our limitations. Unfortunately, we know so little about human intelligence and the theoretical models describing its functioning are so poor, that the possibility of applying this knowledge to the man/machine interaction is restricted by our lack of understanding.⁵ Every step forward, however insignificant it may be, in the field of the theories of intelligence will be magnified by its translation into new material montages. Fortunately, net.art and digital art are providing evidence of its evolutionary potential.

7. Social environments and collaborative creative spaces

The third pillar of literacy is the less known yet not less important for that. It involves social environments and collaborative creative spaces, as well as the complex social pressures that structure us as groups. The most interesting thing here is the subtle network that exists between intellectual capabilities and the social framework of cognitive development and vice versa.⁶

Andrea di Sessa (2001)—with that added value so unique to him focused on improving our understanding of mathematical literacy in order to enable the comprehension of computational literacy in general—offers a solid example of this graceful and eternal golden braid. Isaac Newton was, beyond doubt, the creator of infinitesimal calculus. In this sense, Newton was a predecessor of Freud, who, through his own self-analysis and by means of a resourceful process of development and discovery, invented psychoanalysis and created a methodology that he later developed into a doctrine.

In order to discover/invent the unconscious, Freud set out to create all the categories that he required to reach his objective. In like manner, Newton invented the intellectual infrastructure for his own accomplishments in understanding mechanics, the science of force and motion.

We are referring, obviously, to infinitesimal calculus, a founding moment in history when a new material intelligence emerged out of the specific needs of a scientific investigation. In this

perspective, the calculus is a way of writing down and drawing inferences about various aspects of changing quantities. Newton wanted to reason about instantaneous properties of motion that were difficult to capture using prior material intelligence. Nonuniformity and constant speed situations which were adequately handled by prior techniques, simply were not up to dealing with facts in a constantly and nonuniformly changing situation as the movement of the planets around the sun.⁷

8. Newtonian machines and Ascottian machines

Based on all the above, we can affirm that the Newtonian revolution also led to the invention of a new material intelligence the current validity of which (aside from its limitations when it comes to dealing with micro- and macrocomponents, as corrected by Einstein) is plain to the eye and cannot be ignored. Newtonian machines not only paved the way for technology and engineering, science and architecture, but also infected all our intellectual categories (including paradigms and theories of history) and, despite the existence of many manifestos to the contrary, we have still not succeeded in becoming immune to them. However, this is another question altogether.

After Newton, causality became local and there was no such a thing as an action at a distance, whatever unrepentant spiritualists might contend. What is far less known⁸ is that the fantasy of a material intelligence emerging like Pallas Athena from Zeus' head is a fiction of the imagination of a single mind. This notion totally ignores⁹ that surmising that calculus emerged as a finished product from Newton's head is a pleasing yet dangerous and distorted invention.

This is so because Newton not only based his accomplishments on certain situations and designs developed by Galileo himself, but also because the more general version and the final notation that we still preserve and praise were not developed by Newton but by the brilliant (though far less acknowledged) G.W. Leibniz.¹⁰

It is not our intention to undermine Newton's stellar role in history. Instead, we wish to cast light on the cumulative nature of innovations and inventions that correlate with the issue of computational literacy and, more specifically, with digital art as material intelligence. It is of little avail to restrict to isolated or privileged circles the use of computing tools (from the primitive spreadsheet invented for personal computers in 1978 up to the super computers of today, from grid computing to social bookmarking, from cyber art installations, hacktivism to TAZ—technological autonomy zone).

The real challenge lies in making these powerful and sophisticated tools available to the masses rather than restricting their use to the requirements and whims of an elite—without giving any thought here to the dangerous connivance encouraged during the past decades between engineering, patenting, intellectual property rights and business operations that widen gaps rather than contribute to close them.

However, the question here involves considerably more than stressing the importance of accumulation, the weight of history and intellectual heritage. Newton was the great visionary, but Leibniz was the facilitator. Without the lower cognitive cost afforded by his notations, mechanics and related sciences would have probably taken far longer in developing and advancing.¹¹

Though here again we would have to resort to some sort of counterfactual experiment to prove this assumption, there is no doubt that infinitesimal calculus took two centuries to become the *koine* (the common basis of understanding) of scientists and engineers worldwide. Di Sessa contends—and we are absolutely convinced that this is true—that without the intervention of Leibniz the history not only of calculus in the Western world but also of modern science itself would have been significantly different and not necessarily for the better.

9. Hypercomplex dynamics of innovation in science, technology and techno-art

The conclusion we can draw from this preliminary analysis is more than evident. The emergence of literacy in the form of a material intelligence constituting the basic structure of knowledge is dependent on highly complex innovative social forces, adoption and the interdependence of multiple agents (and sometimes of nature itself transformed into a social actor, as Latour sustains), regardless of whether it is triggered by an isolated individual or by a specific community. If we give credence to the butterfly effect, and by reference to this example that has many equivalents in

history, it is clear that insignificant differences in learning (like the transition from DOS to Windows) have vast implications in the dissemination, incorporation and reinvention of new practices and worlds.

The consequence is no less significant. Even nowadays, math literacy is a tremendous barrier and obstacle for the cultural and social development of humanity. While a select few enjoy taming this science, for most of the world's population math ranges from a simple nuisance to a source of pain and discouragement.

If, on the other hand, we envisioned mathematics training as a key link in the infrastructure of social and economic development and if we made use of the countless new computer-specific visualization tools,¹² there would probably be greater chances of achieving the desideratum within a measurable and reasonable period of time.

The same applies *ceteris paribus* to computational literacy that will occasionally facilitate math literacy but more often than not is dependent on it.

However, what we wish to highlight in this case (expanding on an issue that Di Sessa suggested but did not develop) is a far wider infrastructure of knowledge that encompasses not only the teaching of maths according to these guidelines, but the teaching of biology, design, aesthetics, quantitative history and what have you. This applies, in particular, to techno-art.

Each of these disciplines—recycled in accordance with the paradigms of visualization, interactivity, massivity and hyperrelations that render possible computerized treatments based on plausible and intelligent assumptions, some of which can be verified in Sardón's works—will provide a basic link in rebuilding the infrastructures of knowledge and ensuring their dissemination.

This combined action is essential if we intend to ensure a mass, systematic computational literacy capable of being assimilated by the coming generations and of building on existing intelligences such as linguistic and logical-mathematic intelligence by adding many other multimedia and emotional intelligences.

The process is not linear but resourceful. There is no magic bullet here but rather one thousand possible beginnings (one thousand middles and one thousand ends). Above all, and judging from the ideas outlined above, what we need is some sort of yeast of a yet undetermined nature that contains the rudiments that must be “sown” and “planted” socially.

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¹ The process involved in becoming phylogenetically human as a species as sustained by Merlin Donald in *Origins of the Modern Mind. Three Stages in the Evolution of Culture and Cognition*, and ontogenetically as disparate and specific groups, at the same time both similar and different, with an awareness of intention that arises in human infants at about nine months of age, according to Michael Tomasello in *The Cultural Origins of Human Cognition*.

² We should not forget that by 1980 a pioneer like Frank Popper (1989) was already addressing issues such as new forms of art, action and participation prior to the existence of personal computers and at a time when mass Internet was unthinkable.

³ Mariano Sardón theorized on these topics in articles such as “An Approach to Relational Artworks as Complex Dynamical Systems. Subtle Technologies” (available online at: http://www.marianosardon.com.ar/toronto_eng.pdf), or in “El arte como investigación” (available online at: http://www.marianosardon.com.ar/arte_tecno_esp.pdf).

⁴ We recommend an in-depth analysis of the work of Bruno Latour, “Drawing Things Together”, in Michael Lynch & Steve Woolgar (eds.), *Representation in Scientific Practice* (available online at: <http://www.bruno-latour.fr/articles/article/21-DRAWING-THINGS-TOGETHER.pdf>).

⁵ This explains the interest generated by the proposals put forward recently by Merlin Donald with relation to the transition from episodic intelligence in primates to abstract intelligence in humans through mimesis and myth, and the thesis advanced by Michael Tomasello on the early awareness of the intentions of others as a distinctive feature of hominization.

⁶ Over two decades ago, Gavriel Solomon was making headway in these investigations with the assistance of the everlasting contributions of Vygotsky’s work, without even imagining that the Web 2.0, and the tools of social software in particular, would transform these theoretical desiderata into a field of cooperative construction of meaning for hundreds of millions of people.

⁷ There are entire treatises and libraries (including an outstanding little book like I.B. Cohen’s *El nacimiento de una nueva física*) that show how the combined work of Copernicus, Galileo and finally Newton changed not only physics (from the study of things at rest to the study of things in motion), cosmology (from the closed world to the infinite universe, as described by Alexandre Koyre), anthropology (by inflicting on it the first of the three most brutal blows in history to its narcissism—added to those later inflicted by Darwin and Freud, as Bruce Mazlish explains), but would also provide a model to envision the path leading from representational art to propositional and participatory art.

⁸ This explains why the history of science is urgently in need of an in-depth revision such as the one that is being carried out by Steven Shapin, Harry Collins, Steven Woolgar, Bruno Latour and John Law, amongst others.

⁹ Fortunately, in the descriptions of the evolution of science and recent technology this multicausality is acknowledged more easily, as in the case of the fundamental freedoms that enabled the making of the Internet. See Tuomi, Ilkka, *Networks of Innovation. Change and Meaning in the Age of the Internet*, New York, Oxford University Press, 2002.

¹⁰ Though Di Sessa himself admits he cannot prove it, the reason behind the incorporation of a mainly pedagogic notation (something like this, but far more sophisticated, as in the transition from the DOS commands to the drag-and-drop in Windows) was the lower cognitive cost afforded by this new notation. For example, in Leibniz’s notation the rate of change of a quantity, x , given a small change in another, t , looks like just what it is, a ratio, dx/dt (Newton’s notation is opaque, an x with a little circle on top of it, that is impossible to reproduce here). Moreover, Newton’s notation dealt with changes in time (his famous fluxions) so he pretty much had to state this theorem for the case that y is time, and he had to do it in words that hide the real generality of the theorem.

¹¹ An analogy can be made with the development of science in China, an issue that was investigated in depth by Joseph Needham.

¹² The animated short *Donald in Mathmagic Land* (1959) shows how it is possible to learn about fractions, the Pythagorean theorem, the golden section and many other things in a visual manner that very few others attempted to emulate.