Chapter 2
Materiality, Learning, and Cognitive Practices: Artifacts as Instruments of Thinking

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Abstract Human cognition generally is construed as an abstract activity involving symbol manipulation in the mind/brain of the individual. A corollary of this position is that the unit of analysis in research is the isolated mind. However, human cognitive practices generally take place in interaction with others, and, furthermore, they rely on the use of (socio-)material artifacts (documents, computers). One of the most distinctive features of *Homo sapiens* is the capacity to convert ideas into artifacts that support intellectual and physical activities, and that later will intervene in our daily practices. In this sense, artifacts are important outcomes of human learning that contribute to the building up of a cultural memory and that give the human mind its distinctive hybrid character where thinking relies on the use of artifacts that have emerged in society. As a consequence innovations continuously change our cognitive practices and capacities as is illustrated in the chapter.

Keywords Learning and artifacts · Cognition and materiality · Cultural tools · Cultural memory · Socio-materiality and thinking · Symbolic technologies · Learning in everyday life

Introduction

In experimental psychology there is a phenomenon referred to as "tip-of-the-tongue" (or "TOT"). This phenomenon, vividly discussed already by James (1890), refers to the familiar feeling of almost recalling a piece of information, be it a word or part of a word, a name or the title of a book or picture. We feel that "recall is imminent" as Brown and McNeill (1966, p. 325) put it in their seminal study of attempting to induce TOT experimentally. As a feeling that is part of everyday life, TOT is widely recognized outside the narrow circles of experimental psychologists. In a study by

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Reason and Lucas (1984), more than half of the respondents reported experiencing TOT like states every week (cf. Brown, 1991, for further discussion of when and where TOTs occur). Research on this phenomenon continues to this very day in fields such as memory, psycholinguistics, language learning, and so on (cf. Lampson, Gray, Cibas, Levy, & Loscalzo, 2016; Pureza, Soares, & Comesaña, 2016).

TOT poses a challenge from epistemic, theoretical and methodological perspectives for studies and research questions explored in this volume on issues of materiality and cognition. While TOT is a well-documented and robust phenomenon, and there is a vast number of empirical studies that testify to its existence, it also demonstrates a dilemma. If we want to understand how people deal with such states of mind and what they mean in daily activities, TOTs—the focus on recalling information—may not be useful. If we construe the human mind as an autonomous cognitive unit disconnected from external support, we will find that TOTs are probably as common today as they have been, and, most likely, we are no better or worse at solving such challenges than people have been before us. An alternative picture would appear if we analyze how people, in functional terms, deal with such states of mind today as opposed to, lets us say, in the middle of the twentieth century, when the empirical research on TOT took off. The expression "in a functional sense" here refers to the epistemic practices they are likely to engage in when facing such situations; how do they deal with the problem? In the current cognitive ecology of many societies in the world, people will immediately turn to their smartphones and a search engine to resolve a TOT situation. They will enter information relevant for what they are looking for (a part of the word, of the name of a person, of the title of a film, etc.), and they will search their way through the information displayed to obtain what they are looking for. In other words, we rely on external artifacts that connect us to the cultural memory of our society (Donald, 2018), and, in addition, we are currently developing literacy strategies for searching and validating information under such circumstances. The finding of the information in the latter context is a joint achievement involving a person and an artifact with a considerable repertoire of resources for searching, manipulating and displaying information supporting the activity of finding an answer; that is, both constituents of the situation—the user and the technology—exert some agency in the situation. Many of the strategies we have developed in such contexts are recent and follow in the footsteps of the spread of smartphones, the Internet, search engines and constant connectivity; elements of our cognitive and communicative ecology that are recent, appearing during the past 25 years or so. The ways in which we search for information in such settings are different from those that applied to situations in which we had to rely on our own memory or on writing and print technology. As Giddens (2002) argues, our "access points" to knowledge and information have changed, and, as an example, the particular problems of TOTs are now resolved differently as are many other instances of remembering and information search.

When studying, and when trying to theorize, cognitive capacities in a functional sense and as they are part of everyday activities, we thus face an interesting dilemma. Either we construe the mind as an isolated unit processing information detached from bodily, material and social ties and support. As a corollary of this position, we search for cognitive activities by localizing them inside our heads as cognitive schemas or processes; perhaps we even try to localize them in the biological substrate of our brains as is the dominant strategy in the neurosciences. Alternatively, we follow the suggestions by scholars such as the evolutionary psychologist Donald (2010), the anthropologist Lave (1988) and many others of construing cognition as embedded in practices that include other people and material artifacts. Donald suggests that humans, unlike other species, are best conceived as having "hybrid minds" that operate in collaboration with external storages such as texts, maps, calculators, digital media and a range of other "exographic" resources that have emerged through history. Lave argues that cognition is "stretched out" between people and between people and artifacts. In the latter conception of cognitive practices, the mind gains much of its power through the "mergers and coalitions" (Clark, 2003, p. 3) with artifacts that exist in the world and that have become constituents of our intellectual (and other) activities.

Technologies, Learning, and Cultural Memory

Technologies in themselves are products of learning, they testify to the capacity of *Homo Sapiens* to transform ideas into artifacts. By inventing artifacts such as the wheel, hammers, bows and arrows, trains and excavators, humans (and our predecessors in the hominid lineage; the oldest stone tools date back some 3.3 million years and even precede the appearance of *Homo habilis*; cf. Harmand et al., 2015) have extended their physical capacities well beyond what nature has provided us with. Through processes of design, we have altered the world we live in, and, as a consequence, our abilities to perform physical work, to travel, to hunt and to engage in most other activities are not constrained by the natural powers of our bodies. A heavy container can be loaded on to a large freighter by means of a crane controlled by a joystick, and in modern forestry a tall tree will be chopped down, peeled off, sawn into pieces of suitable length and loaded onto a lorry by means of a machine operated from an instrument panel in the relative comfort of a warm cabin. This designed nature of our environment is obvious in almost everything we do in modernity, and few would take issue with the nature and implications of such technological breakthroughs and their impact on our everyday lives.

It is equally obvious that the phenomena that we refer to as cognitive processes have undergone similar changes, provided we accept the idea of a hybrid mind. Our brains are the same, and they have been the same for a very long time, but how we use our brains has been changed. Cultural innovations have radically changed the ways in which we think, reason, remember, perceive and so on. Our capacities for remembering have been dramatically extended by the uses of texts, our visual perception has been amplified by tools such as spectacles, microscopes, binoculars and X-ray technologies, and our capacities for calculating have been transformed by the abacus, the slide rule, mechanical calculators, digital calculators and, in recent decades, by a wealth of highly specialized software, to mention but a few examples.

The cultural evolution during which external support for cognitive practices have developed goes back a long time, although, in comparison to the general development of artifacts, we are still in relatively recent times. Traditionally, the symbolic cultural revolution has often been said to have appeared around 40,000 years ago, but, as archeologists continue excavating, the date is pushed further back in history. At present, the claim is that the earliest preserved instances of intent symbol-making go back some 60,000, which is the dating of the famous engravings on egg-shells found in South Africa by Texier and colleagues (2010). But, most likely, we have not seen the end of this dating story yet (in fact, as this is written, a cross-hatched pattern made with an ochre crayon dating back some 73,000 years has been discovered in the Blombos Cave in South Africa, cf. Henshilwood et al., 2018). Later examples of intent symbol-making are stone-carvings or paintings and various artifacts with inscriptions considered to represent kill scores, lunar calendars and other information (d'Errico, 1998; Marshack, 1972). Even though the interpretations by scholars of what many of these early signs represent often differ (d'Errico, 1989), there is acceptance that they are intentionally produced signs serving memory and other social functions of significance to a community. Thus, what we see appearing in history is what Donald (2010, p. 70) refers to as "symbolic technologies," that is, tools created over millennia to "represent, communicate and store knowledge" and information.

Writing: Cognition Goes Material

The most important symbolic technology developed in the history of humankind is writing. Written language appeared some 5000–6000 years ago, depending on definitions (Harris, 1986; Schmandt-Besserat, 1981) in the so-called city states in Mesopotamia in present day Iraq (Kramer, 1981). Here, a new and much more diversified economy and society with a high division of labor emerged. City-dwellers could no longer cultivate land or keep animals to secure food. The city relied on continuous supply of food and other goods, on transport, and it had to provide other communal resources such as a defense, a legal system, and taxation to fund the infrastructure and services provided. Writing became the technology by means of which such functions could be coordinated and controlled: contracts could be written, receipts issued, people and properties registered, and so on. We see the emergence of "document societies" (Thomas, 2001), where specialized symbolic technologies began to complement the human memory as a repository of information and knowledge.

As Donald (2008, p. 197) puts it, the "human brain is adapted to the existence of cognizing mind-sharing cultures that far exceed the individual in terms of their ability to store and transmit accumulated knowledge and skill." In "mind-sharing cultures," minds, and even brains, and culture coevolve. Extended use of cultural sign systems such as written language and number systems has been shown to affect the patterns of brain activation and lateralization (cf., e.g., Dehaene et al., 2010; Donald, 2010;

Qin et al., 2004). These observations of biological correlates of the uses of exographic sign systems testify to the plasticity and flexibility of the human brain/mind, and an extraordinary capacity to accommodate to changes in external conditions.

The cultural and cognitive dynamics introduced by writing as a symbolic technology, thus, are multilayered and quite dramatic. A written language makes it possible to cumulate information, knowledge and human experiences at an unprecedented level. The cultural memory of a society utilizing written language can expand without any limits, and the cumulation of information and knowledge is in no way limited by memory capacities of individuals or even groups. At another level, writing triggered technological development where new instruments of writing (styli, lead pencils, typewriters etc.) and new materials for writing on (clay, wax, parchment and eventually paper) emerged. Libraries represent another obvious institutional outcome of written language of significance for expanding the cultural memory. The invention of the printing press in the fifteenth century is one of the most transformative technological changes in history. Scripts, arduously produced and expensive, were replaced by printed books that could be mass-produced (Eisenstein, 1985). The increasing capacity for disseminating information and knowledge implied that wide groups of people could avail themselves of the insights documented in the cultural memory. At yet another level, writing changed societies and individuals by providing new conditions for "mind-sharing cultures." Engaging with written language is both an internal, cognitive act of reading and/or writing, and, at the same time, writing is "out there"; it exists along with other social artifacts of culture, and forms part of a broader social context" (Barton & Hamilton, 1999, p. 799). Thus, the uses of written language—that is, literacy practices—changed both minds and societies, people had to learn to make meaning through reading for societies to be able to organize institutions and daily practices by means of written language. And, vice versa, for societies to develop, the minds of citizens had to be shaped through instruction and systematic training in the context of schooling in order for them to participate in literate practices. These consequences of writing for human cognition have been demonstrated through a large number of research studies ranging from neuroscience (cf. above) to psychological and anthropological inquiries (Goody, 1986; Luria, 1976, cf.; Scribner & Cole, 1981). This development is a clear illustration of the idea of coevolution of minds and symbolic technologies.

Put differently, written language (in a broad sense and including representations such as maps, drawings, and registers) serves as the interface between individual minds and the cultural memory. That is why it occupies such a central position in many societies, and why most representatives of contemporary education stress the importance of improving literacy skills. In addition, a cultural memory organized in this manner exerts a powerful impact on the cognitive (and physical) practices in society. It is thus not a passive container storing the past. As Donald (2018, p. 21) puts it, the:

> memory system of a culture is thus much more than a repository of past experience and knowledge. It is also an active cognitive force that influences thought and the representation of reality. It structures the collective individual activity of a population by linking together, in a set of complex social networks, the cognitive resources of an entire population. Within its embrace, networks of people exchange perceptions of reality, make decisions, share

> memories, form consensus on what will be remembered (and forgotten), and stimulate one another to generate thoughts and representations that are otherwise extremely unlikely to appear in socially isolated individuals.

While writing serves important functions for storing information and knowledge, it thus also exerts cognitive force and provides powerful means of organizing and manipulating information in collaboration with the artifacts of culture that are integrated into our practices. Examples of this are plentiful in history. The emergence and use of tables and tabular representations shortly after the invention of writing in Mesopotamia are an interesting case in point (cf. Campbell-Kelly, Croarken, Flood, & Robson, 2003). In tables, information could be organized in two dimensions by means of rows and columns. The unit thus created—in something that we today recognize as a cell—represented information under a heading, such as salaries during a given period. On the rows, the names of the recipients, such as priests, soldiers or public servants, could be given. This intellectual technique served important documentary functions in increasingly complex administrative routines. But, in addition to documenting transactions, the tabular representation became a thinking tool with features such as totals and subtotals in two dimensions, where the information in the columns and rows could be summarized, reflected on and argued about (Robson, 2003, p. 26). These procedures paved the way for important abstract functions such as auditing of transactions, and they provided overview over complex social activities.

The tabular representations that go back some 4500 years must be seen as major cultural and intellectual breakthrough with consequences for the future and for activities in many corners of society: astronomical tables, logarithmic tables, nautical tables, and so on. They may also be seen as predecessors of spreadsheets in the digital age. Appearing in the 1970s, the spreadsheet (with Microsoft Excel as the most well-known software) represents a continuation of the paper-based table in terms of how the information is organized in two dimensions on the screen. But in a sociogenetic perspective, and even though the "screen of a personal-computer shares the two-dimensional character of a writing surface," it has "two additional properties—easy erasure, and the ability to act as a "window" onto a much larger virtual surface" (Campbell-Kelly, 2003, p. 324). Easy erasure implies that the information can be altered and that the consequences of such changes become visible throughout the table. The flexibility that this affords implies that the user can manipulate the values in order to analyze the material and, in addition, ask "what if" questions as Campbell-Kelly points out. From a cognitive, and practical, point of view this is a very significant feature of the spreadsheet in the sense that "what if" questions are interesting for modelling, planning, and evaluating hypothetical alternatives in many settings, for instance when taking decisions on investments or other economic transactions and when attempting to predict future developments.

The capacity of the spreadsheet to work as a "window" onto a virtual world implies that it operates as a resource for managing and analyzing an infinite number of data sources and databases where the logic of the organization of information in spreadsheets is functional. Thus, the spreadsheet operates as a key or grid that stretches out into a world of data and databases that are formatted in compatible manners. Databases may be designed, built and exchanged, and they may be bought and sold across the world just as any other commodity. The operations to be performed by users are structured partially through the particular formatting, partially through the interests and capacities of the user in a situated practice. Both elements of the activity are necessary: symbolic technologies and capable human minds in search of information or knowledge.

Materiality as Constitutive of Cognition

At a very general level, the engagement with material objects has always served as a trigger of human thought and conceptual development (Malafouris, 2013). It is by externalizing ideas and attempting to implement them in physical form that human conceptual resources have expanded. In designed worlds, there is thus an intimate link between materiality and cognition, and, as Cole (1996, p. 117) puts it, artifacts "are simultaneously ideal (conceptual) and material." The very existence of an artifact is premised on the fact that material objects have been transformed and shaped by ideas and practices.

This duality is even more obvious in the case of symbolic technologies as illustrated in the evolution from Sumerian tables to contemporary spreadsheet software: we are dealing with material and conceptual entities that have been shaped through history and that are implemented in artifacts, and sometimes refined over centuries or even millennia. An important point here is that these technologies are not just representations of the world, rather they are constitutive elements of the enactment of thinking and reasoning in social practices where they serve as powerful "cognitive amplifiers" (Nickerson, 2005).

In the perspective outlined here, artifacts and cognition are intertwined in a distributed and constantly evolving system of thinking and symbolic technologies by means of which human reasoning is enacted in practices. Thus, documentation is more than mere registration of information. It is a cognitive act per se where issues of what and how to document have to be addressed, and documentation provides overview and systematicity where a complex reality can be simplified and made transparent (Mäkitalo & Säljö, 2002). Later, capacities to manipulate and operate on what has been documented have increased through the invention of intellectual techniques (such as those inherent to tables and spreadsheets) and artifacts (such as calculators, computer software). Such developments imply that current users of artifacts and conceptual systems operate on the basis of experiences that stretch over long periods. Many of the decisions that have been taken in the design of mundane artifacts have been "black-boxed" and are not attended to by the user as Latour (1999) argues. The user of a digital game or a search engine may have very little understanding of how the technology functions, but they can still become very skilled users of the artifact.

But this coordination between minds, materiality, and symbolic technologies is at the heart of the human capacity to think, learn and transform reality. In a sociogenetic perspective this is visible in artifacts such as rulers, compasses, clocks, speedometers, databases, and navigators, which represent not just a material legacy from previous generations but also an intellectual one. In contemporary society we are witnessing an intense evolution of such technologies with increasingly specialized functions. The traditional online calculator has been further specified in its design to adapt to the needs of currency conversion or to serve as a tool for house buyers when estimating costs for mortgages at different interest rates. The conventional weather forecast has been supplemented by apps with dynamic weather radars that make it possible to follow and anticipate the weather across the globe. The algorithms built into such symbolic technologies remain largely hidden for users, who need to understand how to enter information and how to evaluate the outcomes.

An illustration of such a process of developing a symbolic technology that allows us to conceptualize complex events has been analyzed by (Fauville, Lantz Andersson, Mäkitalo, Dupont, & Säljö, 2016; Lantz-Andersson, Fauville, Edstrand, & Säljö, in press). We explored how the problems of human impact on the environment may be visualized and communicated in a transparent and relevant manner in order to support education, public awareness and political debate. This has been achieved through the invention of a highly specialized artifact, the Carbon Footprint Calculator (CFC). The concept of Carbon Footprint (CF), originally based on the metaphor of an Ecological Footprint, was invented in the 1990s (Wiedmann, 2009). CF is defined as the amount of CO_2 and other greenhouse gases produced by a person's activities in a given timeframe. The basic idea is that people report on their daily activities in areas such as housing, transport, food habits, shopping etc. Figure 2.1 illustrates a part of the home energy and appliances section of a CFC (www.i2sea.stanford.edu/calculate).

When the person reports on his or her heating system and enters her values into the different boxes, the calculator converts the information to CO_2 emissions expressed in kilograms. At the bottom of the page, the value obtained may be compared to averages of the country the person lives in or of the world. The interface is familiar for anyone who is digitally literate, and the nature of the task of entering values is familiar. The outcomes—that is, the estimates of footprints from various activities—may then be integrated into reasoning and arguing in discussions of various kinds of comparisons and when considering how one can reduce one's own footprint by changing habits. Thus, this symbolic technology lends itself to exploring a range of "what if" questions of concern for educational settings but also for citizenship and decision-making in everyday life.

In the wake of these developments of citizens gaining conceptual access to their footprints, other consequences may follow. For instance, houses and products such as cars, dishwashers or fruit will be sold with information about their impact on the environment. In this sense, public awareness of how to address environmental problems may increase. What a symbolic technology of this kind does is that it structures and gives users access to a topic that would be difficult to address in any other manner. The concepts themselves are abstract and the calculations built into the device would be difficult, if not impossible, to engage in without the tool. From

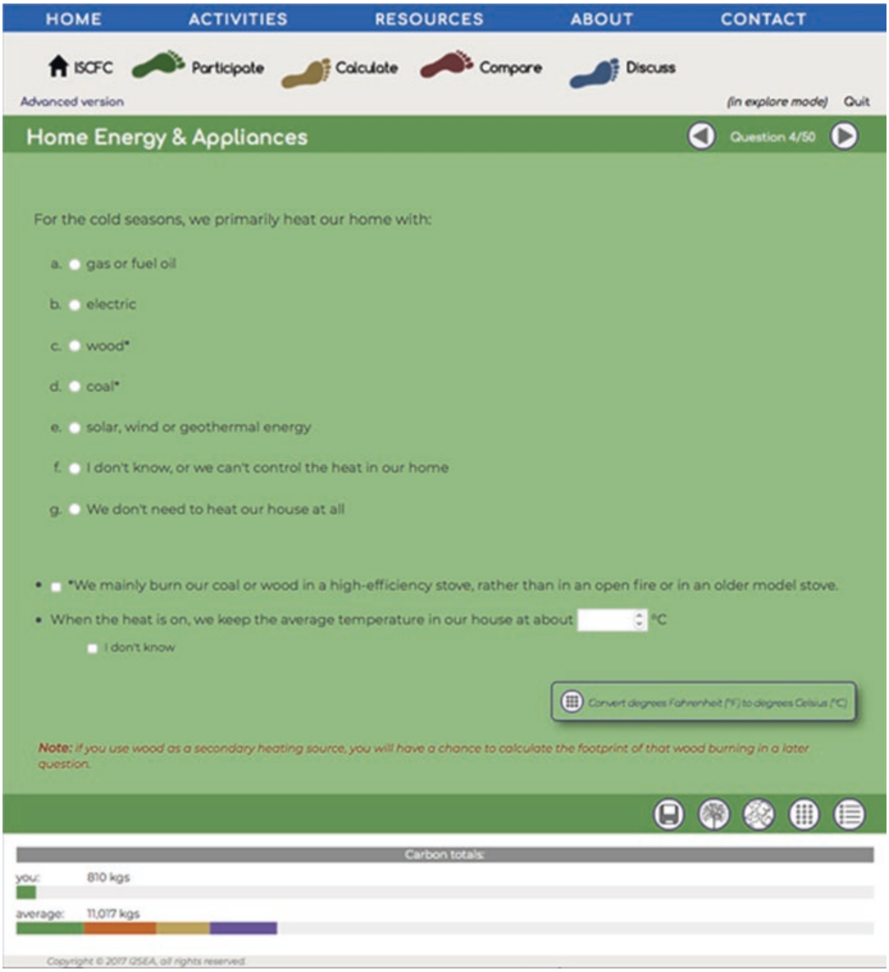

Fig. 2.1 Home energy and appliances section of a Carbon Footprint Calculator (permission Géraldine Fauville; www.i2sea.stanford.edu/calculate)

a cognitive point of view, a technology of this kind illustrates of how tools allow us to explore and reason about more than what we in some sense know (Wertsch & Kazak, 2011). By using the CFC we can structure a problem and convert various sources of information to arrive an aggregate output that is relevant for learning and for citizenship in contemporary society. Thus, the symbolic technology does far more than calculate. It is a conceptual tool that structures a problem in ways that make it accessible for reasoning about complex issues.

Of course, symbolic technologies of this kind require competences and skills of users, and they are black-boxed. Most users will not understand the assumptions regarding climate change that are built into tools of this kind, and there will also be conflicts among experts about exactly how estimates should be made and what algorithms that are accurate. Thus, trust will be a matter of concern in such settings.

Conclusion

It is interesting to observe that current perspectives on learning and cognition, and the role of symbolic technologies for thinking, were anticipated in Vygotsky's (1981) thinking almost a hundred years ago. In his short essay "The instrumental method in psychology" he sketched his ideas about the role of "cultural tools" for human learning and knowing. In this short text, originally a lecture, he argues that tools are constitutive of what he refers to as "instrumental acts" of thinking. In such instrumental acts, "artifical formations," that is, human-made signs and sign-systems, reorganize mental functioning and introduce "several new functions connected with the use of the given tool and with its control" (p. 139). Such an artificial tool also often "abolishes and makes unnecessary a number of natural processes, whose work is accomplished by the tool." (*loc. cit.*). The examples given illustrate how cultural tools, symbolic technologies, are integrated into our thinking (and communication), and how they—in Vygotsky's terms—contribute to reorganizing intellectual practices and instrumental acts of thinking and arguing. In this sense, artifacts may be physically out there, but in spite of this, they are constitutive elements of the thinking and knowing of a hybrid mind.

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