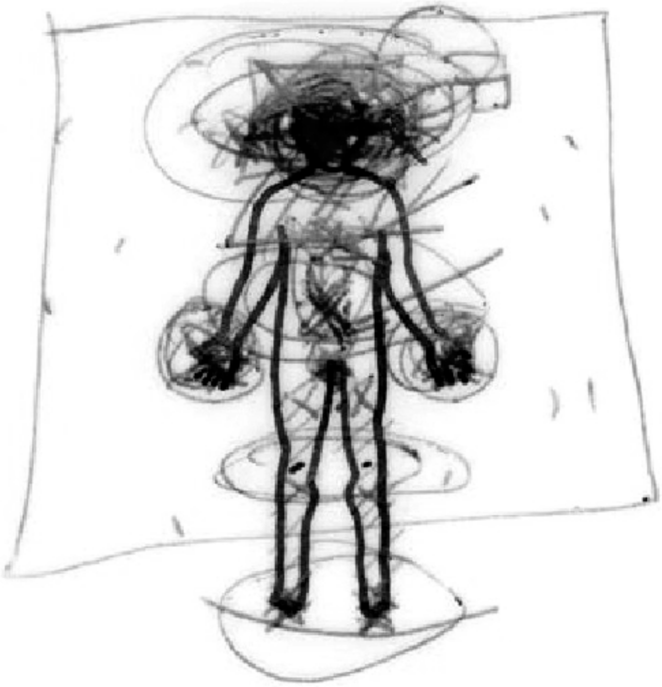
Cyber-Archaeology

Edited by

Maurizio Forte



BAR International Series 2177
2010

Published by

Archaeopress
Publishers of British Archaeological Reports
Gordon House
276 Banbury Road
Oxford OX2 7ED
England
bar@archaeopress.com
www.archaeopress.com

BAR S2177

Cyber-Archaeology

ISBN 978 1 4073 0721 3

Printed in England by 4edge, Hockley

All BAR titles are available from:

Hadrian Books Ltd
122 Banbury Road
Oxford
OX2 7BP
England
www.hadrianbooks.co.uk

The current BAR catalogue with details of all titles in print, prices and means of payment is available free from Hadrian Books or may be downloaded from www.archaeopress.com

Comparing tangible and virtual exploration of archaeological objects

David Kirsh
UCSD

Abstract

Can virtual engagement enable the sort of interactive coupling with objects enjoyed by archaeologists who are physically present at a site? To explore this question I consider three points: 1) Tangible interaction: What role does encounter by muscle and sinew play in experiencing and understanding objects? 2) Thinking with things. What sorts of interactions are involved when we manipulate things to facilitate thought? 3) Projection and imagination. Archaeological inquiry involves processes beyond perception. Material engagement of things stimulates these processes. What must be present in a virtual environment to recreate the feel of material engagement? I conclude that nothing, in principle, prevents future virtual environments from supporting this material engagement of digital versions of artifacts. But, there is much that remains to be understood about how to realize this material engagement, both at a technological and a cognitive level.

Archaeological exploration is an embodied, material activity. To understand the function of physical fragments, archaeologists heft objects and feel their balance; they closely scrutinize them, they hold them at a distance, or place them against a background of other objects. Whether or not mental projection and imagination are deemed valid archaeological methods, they are still vital elements in inquisitive minds, and the physical act of working and playing with material objects stimulates both. Can we create enough realism with the digital objects populating virtual worlds to duplicate the cognitive feel of real artifacts? Can we re-establish the 'enactive' context needed to reproduce the cognitive processes that archaeologists enjoy in the field?

In focusing on the challenge that virtual archeology faces in recreating the cognitive depth of material engagement, I do not in any respect mean to question the special qualities that virtual archeology offers to archaeologists and the public. As others have discussed, virtual worlds allow us to communicate ideas at a distance, to collaboratively role-play with artifacts, to add or swap virtual backgrounds to contextualize our encounter, or to recreate elements of a dig forever lost. Because it is easy to augment any virtual scene with digital objects, it is easy to add computational elements that reduce the cost of information search, information visualization, and visual comparison. Scenarios can be created and history brought to life. There is little doubt in my mind that archeology will move increasingly in a digital direction both for archaeologists on site, who may wish to augment local reality, and for an enthusiastic public interested in virtual tourism and cultural inquiry.

FFrom a cognitive perspective, however, the question of how physical involvement with objects affects cognition remains an open and very active question. Many of us believe that by interacting tangibly with objects we get something more than by observing images of those objects, even 3D or holographic images. By interacting through a broad range of modalities – touch and manual manipulation in addition to sight and sound – we interactively couple with objects in ways that actually extends cognition. If it is true, then, as many have argued, [Clark 2003, Hutchins 2005, Kirsh 1995, 2009, 2010, Latour 1986)] that humans can literally 'think' with objects, how can virtual engagement support the sort of thinking with things enjoyed by archaeologists who are physically present at a site?

This question can be stated more bluntly. The practices of archaeologists in the field involve more modalities and more material engagement than are likely to be supported in virtual environments for some time. My objective here is to understand what more being in a physical world gives archaeologists.

To explore this issue I consider three points:

1. **Tangible interaction:** What role does encounter by muscle and sinew play in experiencing and understanding objects?
2. **Thinking with things**. What sorts of interactions are involved when we manipulate things to facilitate thought?
3. **Projection and imagination.** Archaeological inquiry involves processes beyond perception. Material engagement of things stimulates these processes. What must be present in a virtual environment to recreate the feel of material engagement?

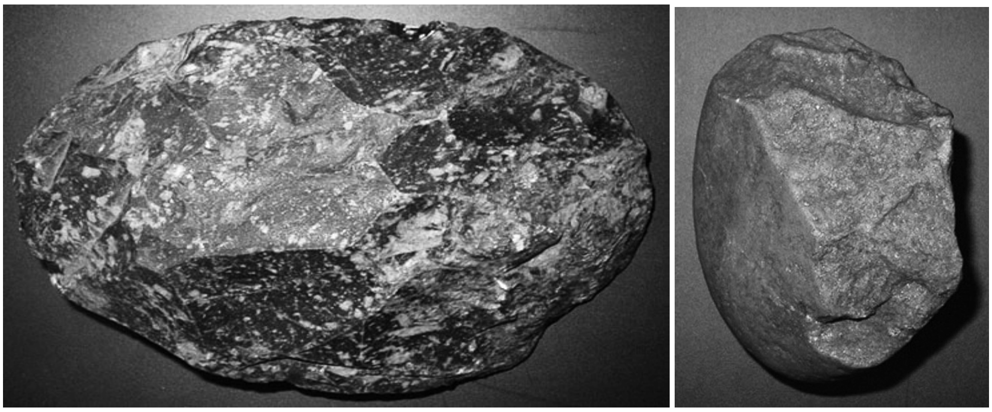


Figure 1. Cutting tools from the New Stone Age.

Tangible Interaction

Look at the stones in figure 1. To an expert eye, the marks of artifice are apparent. Natural processes could, by chance, create such a thing; but the planes and facets have a rational structure that suggests purpose. How can one tell?

Two techniques help: hefting and drawing.

Hefting is the action of weighing and feeling the momentum of an object by moving it in a jerky manner. A stone made for chopping hefts differently than one made for cutting. Because of the distribution of mass moments, certain motions that feel natural with a chopping stone feel less natural with a cutting stone. This feel is only occasionally detectable by sight. Only sometimes can you tell by looking, whether an artifact will fit in the hand comfortably, and even less often can you tell which movements will *feel* most natural. Feel is sensitive to density and mass, and both are invisible. Sometimes affordances that are invisible to the eye are apparent to the working hand.

Today's virtual environments typically fall short on modalities such as touch, heft, smell, and so on. Pressure sensitive gloves, near-field haptics and more, are important input output devices in the laboratory. But hefting goes beyond standard virtual simulations of touch and feel. Hefting lets us perceive the distribution of weight and inertia. To recreate the 'feel' of an axe head, its mass at different points must be known.[1] Of course, this can in principle be achieved in virtual environments. But at present few, if any such environments do. They should.

The consequences of depriving a scientist of these observations goes beyond the phase of inquiry where a conjecture is being tested. It affects the conjectures that are likely to come to mind. In a world without touch, we would expect fewer touch related hypotheses; fewer conjectures about the function of an object that are based on invisible modalities. In short, reduced imagination. Imagination is a topic we will return to later.

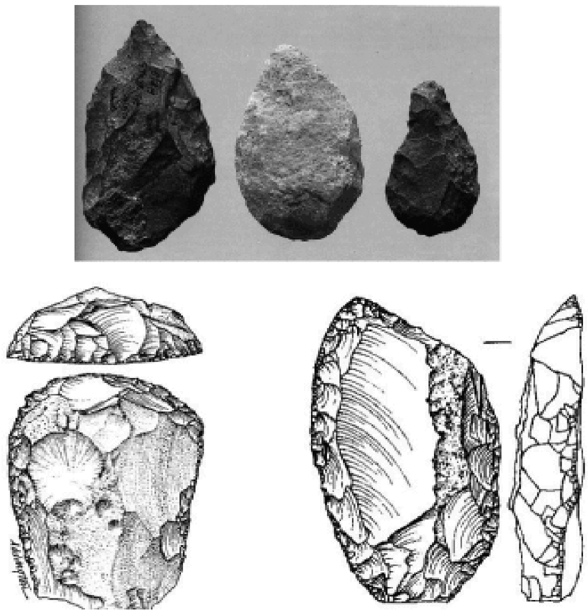


Figure 2. Three Paleolithic stones are shown in the upper part of this figure. Below are two examples of lithic illustrations, though of different stones. Note how much easier it is to identify the way the stones were knapped.

Drawing. A second, and rather surprising, method for determining whether a given Paleolithic stone is a cutting tool is to *sketch* the stone. See figure 2. Not just any form of sketching will do. There is an expert mode of sketching for Paleolithic objects codified in a set of principles of 'lithic illustration'.[2] Good archaeological illustrators will draw a lithic stone to reveal the physical 'problematic' the tool cutter faced. They will show the "scale; the pattern,

[1] In studies of motor perception, for instance, Carrello & Turvey (1996) found that subjects were able to determine the shape of a the information through hefting and wiggling a stick with a weight on it was sufficient to allow computing the inertia tensor of the object. That is, we are sensitive to the inertia of the mass at all points in the object (its mass distribution).

[2] Addington (1986).

sequence, direction, and force of blows to the stone; the bulb and platform of percussion; areas of retouch, snapping, and truncation; areas of grinding, battering, or abrasion; fractures caused by heating; the effects of materials; and pitting and sickle sheen."[3] Potentially confusing features of the stone such as embedded fossils, variegated coloration, patina, seams, banding, and crystallization are left out of the drawing.

The implication is that expert illustrators, when practicing their craft, are forced to scrutinize stones in a special way. They coordinate hand and eye to interactively probe the stone to reveal knapping related features. The need to draw certain lines drives perceptual inquiry. Attention must be managed, and arguably, without the need to sketch, without the presence of an external structure that the illustrator is creating, attention would not be managed adequately. Of course, this is an exaggeration. Illustrators have professional vision[4] and so can see elements of what they would draw without actually drawing. But in drawing, the process of making lines and ensuring they are spaced revealingly, is itself a process that simulates knapping. Using a pencil to draw a curve is physically related to using a knapping stone to flake a chip off a stone. It physically simulates knapping. So, the drawing process can help the illustrator walk through the history of the axehead's making. The drawing is an external representation, and the process of making this representation is a powerful method for structuring attention. It helps the illustrator to figure out what an artifact is by studying 'the details of its making' (ibid).

Simulating behavior. Illustration is a method of simulation that works indirectly by managing attention. A more direct method of understanding an object is to work with it manually. A third reason why tangible interaction adds something to perception *simplicitur* is that without physical interaction it is much harder to tell the multi-sensory ways an artifact might be engaged in a culture's practices. The role objects play in a culture is constantly surprising.

For instance, in figure 3, a person is shown rubbing a Chinese water bowl. When the metal handles of the bowl are rubbed the vibrations cause standing waves in the water. The creators of the bowl engraved four dragons on the base plate to make it seem as if they are spitting water. Now imagine you discover such a bowl at a dig. You see the bowl as a portable container that would probably hold liquids without leaking. But why the dragons, and why the large handles? They seem larger than is necessary to facilitate carrying. Might they play a role in a ritual?

How would one decide? The usual method calls on knowledge about cultural practices at the time, about religion and social rites. Naturally, it is vital to study the details of the room in which it was found, what was its location in the room, what was nearby it. All these things help to support one view or another. But why would one ever suppose that the placement of the dragons was related to the physical behavior of water when rubbing the bowl's handles? Without the chance to engage the artifact physically – to fill it with water and rub it – why would such a conjecture ever come to mind?

Figure 3. Water springs up from the mouths of four dragons, engraved on the bottom of the bowl.

It is an empirical question whether people are likely to consider an artifact to have a function that requires actions unavailable to them. But, even if an archaeologist were to entertain that conjecture, how could he or she test it unless they filled the bowl with water? Admittedly, such an interaction could be recreated in a virtual environment. But why would that feature be present? It is not part of the resource system specific to the dig. As designers of virtual environments how can we know, in advance, what may be useful to inquiry? It is hard to anticipate archeological creativity.

How do we think with objects?

Proponents of distributed, situated, embodied, embedded, enactive cognition, and proponents of extended mind – all fashionable views today – accept, in one form or another, that people think in illustrations, diagrams, mathematical symbols and language. When we engage these material things, we do not just harness them, we actually think with them. They serve as material vehicles for thought. I will not review the arguments for this position here. The arguments most readily made, typically, are for material vehicles that represent propositional thought.

Ancient artifacts, however, may mediate thought differently. They may have more to do with non-linguistic thinking. To date, there is no adequate theory explaining how humans co-opt non-propositional things for thought. Pity. Archaeologists would be well served by such a theory. If only we knew how musicians think with their musical instruments, or how a chef uses cooking utensils to think, we might better understand how Paleolithic or later peoples use blades, axes, and fire to think.

[3] http://www.interdisciplines.org/artcognition/papers/7 Drawing in the Social Sciences: Lithic Illustration by Dominic Lopes
[4] The term professional vision was introduced by Chuck Goodwin (1994).

A simple example of object mediated, non-propositional thought can be appreciated by looking at the small artifact representing a boar, shown in figure 4. Behind the boar is its '3D' sketch as it appears in a graphic program. Such graphic programs are used to recreate these artifacts in 3D virtual environments.

How would a child playing with a physical version of the 3D boar experience the boar differently than a child playing with its virtual counterpart?

Consider this. A natural game with the physical version is to animate the toy, to move it around in order to simulate running, rutting, and so forth. Why is this non-propositional thinking? Because during such play attention focuses as much on movement as on narrative. For instance, the child might animate the boar as if it is running toward a wall. Imagination is important in this process. What might the contents of this imagination be? To a physically orient child, the interesting element might be how the boar must stop and then turn around at the wall; or, how a hunter might cut off its exit and trap the animal. Clearly, there is narrative here. But, the value of the story is not so much how it can be glossed in words; its value lies in the physical lessons the child acquires through imitation and play: how to hunt, how to 'think' like a boar.

Might the same form of play take place in a virtual environment? Perhaps. It is an empirical question requiring experimental test. But, if you believe that the look and feel of the toy boar matters, then we share the same bias. It is not that we know there is something intrinsic about 2D objects making them unsuitable to serve as vehicles of thought in the right way. As long a person can interact with an object easily, whether those objects be digital structures on screens, or pencil sketches on paper, they can recruit attributes of those objects for thinking. This is especially true for representational objects such as illustrations, symbols, and so on. People interact with them in a thinking way every time they use them to solve problems. But, if it is hard to interact with these things, if it is difficult to rotate the digital boar, for instance, or if it is hard to move it forward in a way that lets one imaginatively project oneself into it's hooves, then the user's experience will be significantly less in the virtual than in physical worlds, so much so that it the user cannot think with the digital boar immersively.

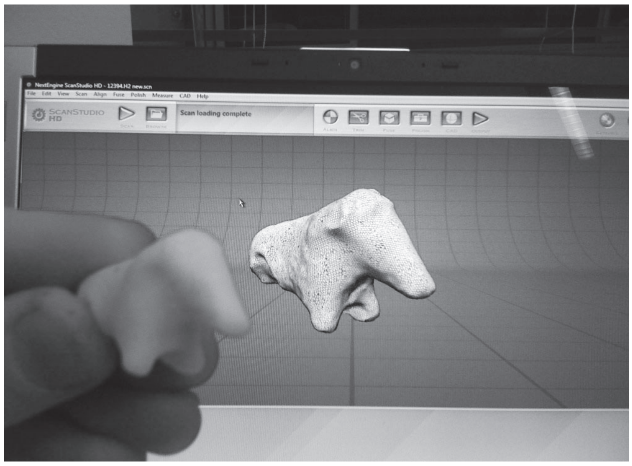


Figure 4. A 3D print of an artifact found at an archaeological dig (Maurizio ref) is held in front of the graphical program that was used to encode its dimensions and drive the 3D printer. It is easy to understand how much more we can do with the tangible 3D object than with its '3D' image using a mouse or wand.

Supporting imagination and projection

It is worth exploring this idea further. I have argued, so far, that engagement with material artifacts can enable thought, and that tangible interaction is often required to stimulate imagination of the function of artifacts. 2D representations, might in principle, serve as vehicles for thought, but it depends on how a thinker can interact with them.

An arbitrary 2D representation, such as a typed or written word, cannot literally be moved once it is written down because it has no material form. It can be re-written in a new position; it can be erased or annotated. But it cannot actually be moved unless its material support, the paper it is on, is moved. In the case of a digital screen, the digital image of word can be moved if it is grabbed by a mouse and dragged. The experience of a person with a 3D toy is quite different. People can reach out and touch toys, they can move them, pretend to make them dance or prance, and so on. How does this change the context of thought?

To explore this deep problem it is necessary to reflect on how a person can appropriate something as a vehicle of thought. Look at figure 5. Can the six pieces on the left be assembled into the target on the right?

Figure 5. Can the six pieces on the right be assembled to create the picture on the left?

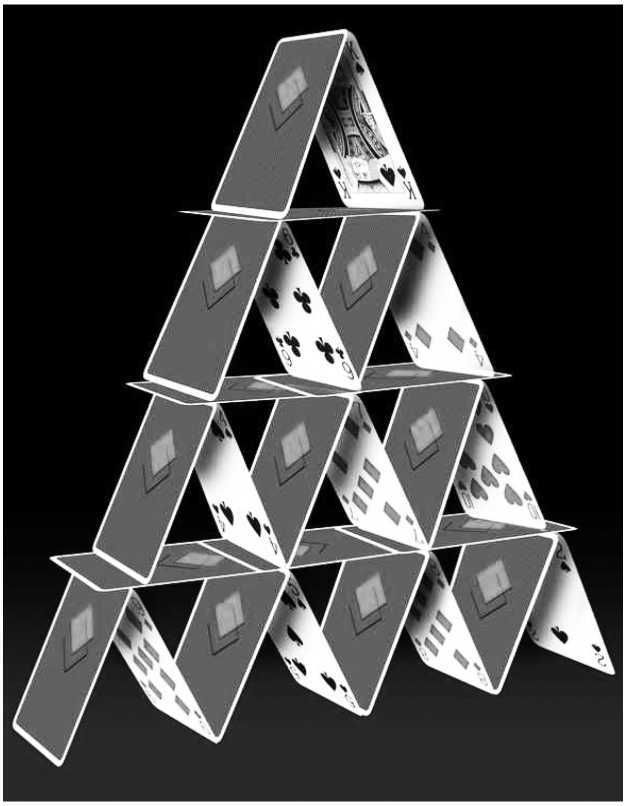


Figure 6. To look at this card tower is to see it as ready to topple at any moment, and most especially as ready to topple if one imagines pulling on a card. This is a form of prospective perception.

We can imagine two conditions: a physical condition where the subject can move the pieces, and physically try assembling them into the target; and a mental imagery condition, where the simulation or proof procedure is performed in the head, presumably through mental rotation and mental assembly. If the mental imagery condition is considered to be thinking, and mental images of the pieces are taken to be vehicles of thought, should we not consider the physical process of rotating and assembling the pieces in the physical condition also to be part of the thinking process? We may be unclear exactly what constitutes the vehicles of thought. For instance, are they the physical pieces, or the changing perceptions of the physical pieces, or the distributed process of moving while perceiving the movement of each piece? But in two out of the three interpretations, the vehicle contains something outside the head. People are assumed to include the pieces as part of their thinking process. Their manual control extends to the pieces, a bit like the way a blind man's perceptual system is extended to include his cane. The result is to extend the envelope of thought to include material things outside the head.

The next step is to explain how this interactive process works. It is my view, that the core interactive strategy of humans involves a back and forth process of projecting structure on the world – seeing the world as it might be after a few plausible actions – and then actualizing one or another of those possible worlds. Our projection or our capacity to imagine is anchored in the world as we perceive it, but we can augment it or partially alter it by making a few quasi-perceptual changes. I say quasi-perceptual because in perception we sometimes experience the world not just as it is at the moment but as it is dispositionally. For example, in figure 6, we do not just see a tower of cards, we see a fragile structure, ready to fall. Its disposition to fall is not a visible attribute, but a phenomenologist would say it is part of our experience of the tower. Certainly, someone who thinks they might pull on one of its lower cards 'sees' it 'as' ready to topple.

If I am right, and a core interactive strategy is to project then actualize then project more, then the trajectory of thought will be sensitive to the actions we can perform. For instance, in figure 7, our capacity to solve the geometric problem will be sensitive to how easy it is to make actual some of the constructions we consider as we reflect on the problem. If it is very hard then subjects tend to do more mental projection before actualizing. If it is easy, then they may not project much more than the line they intend to actualize. They work primarily with their pencil in hand.

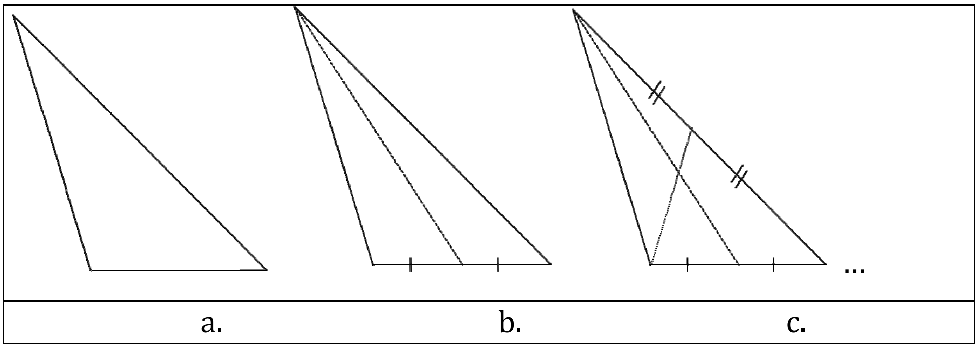


Figure 7. To solve the problem of whether the medians of an arbitrary triangle meet in a single point (the centroid) a typical subject begins by making a diagram then mentally projecting a median, as s(he) begins to think about the problem. Many subjects continue with a second or even a third projection of the median before picking up their pencil again to actualize and annotate their projections.

The point is simple: we are able to project farther into possible worlds, to see how the world might be, if we can physically play with objects. Environments where we can perform these actualizing actions easily, or at low cost, are ones where we will find it easier to think more deeply. We are able to incorporate bits of the external world into our thought processes. For virtual worlds, the challenge is to support this sort of interactive approach. Make it easy to project, then easy to actualize, and so on.

Conclusion

I have argued that cyber-archaeology offers tremendous possibility for extending the cultural and scientific experience of professional archeaologists and ordinary citizens by lowering the cost of adding digital information and visualizations to digs. But to meet the deepest needs of archaeologists, virtual environments must move beyond the purely visual to include the tangible. The need is driven by the very nature of thinking. As we improve our understanding of the way thought reaches out to include material objects we control, it is apparent that archeaologists rely on playing with the material artifacts they discover to deepen their understanding. Nothing, in principle, prevents future virtual environments from supporting this material engagement of digital versions of artifacts. But, there is much that remains to be understood about how to realize this material engagement, both at a technological and a cognitive level. The result will be worth the wait.

Acknowledgements

I thank Maurizio Forte for conversations and encouragement on this topic, and for the National Science Foundation for their support through Project #081386SX SGER: A Study of Following Instruction in Simplified Virtual Environments and Natural Environments: Evidence of Transfer and Comparisons of Cognitive Efficiency.

References

Addington, Lucile R. (1986) *Lithic Illustration: Drawing Flaked Stone Artifacts for Publication*. Chicago: University of Chicago Press

Carrello C., & M. Turvey (1996). Rotational Invariants and Dynamic Touch. In M. A. Heller (Ed.), *Touch, representation, and blindness* (pp. 27-66). Oxford: Oxford University Press.

Clark, Andy. (2003) *Natural-born cyborgs: Why minds and technologies are made to merge*. Oxford: Oxford University Press

Forte, Maurizio. "About virtual archaeology: Disorders, cognitive interactions and virtuality." In, *Virtual Reality in Archaeology.* J. A. Barceló, M. Forte, and D. H. Sanders, eds., pp. 247-59. Oxford: BAR International Series (843), 2000.

Goodwin, Charles (1994) `Professional Vision', *American Anthropologist* 96(3): 606-33

Hutchins, Edwin. (2005) Material anchors for conceptual blends. *Journal of Pragmatics*, Volume 37, Issue 10, October 2005, Pages 1555-1577

Kirsh, David. (1995)The Intelligent Use of Space. *Artificial Intelligence,* Vol. 73, Number 1-2, pp. 31-68,

Kirsh, David. (2009). Problem Solving and Situated Cognition. In Philip Robbins & M. Aydede (eds.), T*he Cambridge Handbook of Situated Cognition*. Cambridge

Kirsh, David. (2010) Thinking with External Representations. AI & Society: *Knowledge, Culture and Communication,* Springer. London. (in press)

Latour, B., 1986: Visualization and cognition. Thinking with eyes and hands, in H. Kuklick, and E. Long (eds), *Knowledge and Society. Studies in the Sociology of Culture Past and Present* Vol. 6, 1-40.

Lopes Dominic: http://www.interdisciplines.org/artcognition/papers/7 Drawing in the Social Sciences: Lithic Illustration