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How does Material Culture Extend the Mind?

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Material Culture and the Brain

Humans rely extensively on material culture when they are thinking, including when they are involved in reasoning tasks that require creative solutions. Examples are measuring devices like compasses and barometers; external memory aids like calendars, books, and maps; calculating instruments like abaci and slide rules; and highly specialized tools like imaging software. Even a brief look around one's desk suffices to indicate that humans are surrounded by artifacts that are specifically designed to perform a variety of cognitive tasks. Why do humans rely so extensively on external tools? What are the kinds of cognitive tasks that material culture helps them to accomplish? How are they instrumental in helping them complete such tasks? This entry of the extended cognition literature will look at these questions in more detail and pay special attention to their relevance to creativity, starting out by considering different ways in which material culture enhances cognition and then briefly reviewing three models of extended cognition. This entry ends by outlining practical applications of the extended cognition literature for innovators.

Extended Cognition: Key Concepts

Epistemic Actions

Kirsh and Maglio (1994) draw a useful distinction between *epistemic* and *pragmatic actions*. Like pragmatic actions, epistemic actions involve some physical manipulation of the external world, for example, a Scrabble player who rearranges tiles on her tray, an engineer who draws a diagram, or a carpenter who makes a pencil mark on a piece of wood to indicate where sawing has to take place. The chief difference between pragmatic and epistemic actions is that the main aim of pragmatic actions is to bring about changes in the world, for example, driving from home to work, whereas epistemic actions are mainly performed in order to aid and enhance cognitive processes, for example, driving around in order to explore the neighborhood one just moved into. Although epistemic actions are primarily aimed at acquiring information and improving cognitive performance, they have pragmatic consequences as well. Drawing a map does not physically alter the environment, but makes it easier to navigate – one does not have to level the terrain or fell trees to get a comprehensive overview. Carpenters who stick to the dictum that one should measure twice and saw once avoid wasting material.

Epistemic actions are often performed in the context of creative problem solving. "Creative problem solving" refers to forms of problem solving that involve the generation of solutions that go beyond established action patterns, or that combine existing ideas in new ways, for example, by applying an approach used in one domain to a different domain. Performing epistemic actions helps one to test run novel combinations of ideas and behavior patterns in a virtual manner, avoiding the costs of real-world trial and error. Epistemic actions are therefore vital to creativity. Examples include an engineer who tinkers with a prototype in order to test the effects of varying parameters to her design and a composer who tests the effects of different harmonic structures in a novel composition by trying them out on the piano.

Epistemic Tool Use

Many animals rely on epistemic actions. Ants make pheromone trails to find their way back from a food source to the nest; birds and other territorial animals frequently inspect their territory to check for intruders. However, tool use specifically aimed at gaining knowledge – known as *epistemic tool use* or *epistemic engineering* – remains rare in the animal kingdom. No animal has ever been observed to make tools (i.e., intentionally modify objects) primarily for cognitive functions. Humans, by contrast, make use of a myriad of artifacts that are specifically designed to help them fulfill epistemic actions. Early examples of epistemic tool use include a 30,000-year-old lunar calendar from Abri Blanchard (French Pyrenees), which not only kept track of the phases of the moon but also of its actual position upon its ascent in the spring sky, and a notched bone from Ishango (Congo) dated to about 25,000 BP, which has notches grouped in numerically interesting ways, for example, prime numbers (De Smedt and De Cruz 2011). These examples predate the earliest emergence of writing by over 20,000 years.

Epistemic tool use is not only ancient but also cross-culturally ubiquitous. Even people with a relatively sparse material culture rely on epistemic engineering. For example, traditionally, Australian aboriginals (who lived a nomadic lifestyle that precludes hoarding large amounts of material culture) used message sticks to relay coded information to distant groups; bark paintings, which captured features of the landscape, like water sources and mountains; and cave paintings, which remarkably preserved biological knowledge of species that have gone extinct for thousands of years, such as fruit bats and giant marsupials (De Smedt and De Cruz 2011). Epistemic tool use is a human universal and has been so for thousands of years. The next sections will review some of the ways in which epistemic tools help humans to perform disparate cognitive tasks, with a focus on creativity.

Lightening Cognitive Load

Perhaps the best-known function of epistemic tools is to extend and supplement human biological memory. Keeping the diverse elements of a complex task in memory is cognitively demanding, and there is always a good chance that some elements get misrepresented, overlooked, or forgotten. By externally representing elements of a task, the mind is relieved from having to represent them internally and can focus better on creative aspects of the enterprise.

Even for those cognitive tasks that can be held in biological memory, it makes sense to use external representations that simplify them. For example, while many people would be able to mentally calculate 231×43, a pocket calculator is faster and less error prone. Drawing up to-do lists, subdivided in urgent, less urgent, and contingent tasks, relieves a person's memory from keeping in mind what to do next and reduces the chance of overlooking pressing assignments. Interestingly, external representations can differ in the way they lighten cognitive load, as Zhang and Norman (1995) showed in their comparison of different numerical notation systems. They found that nonpositional systems like Roman numerals are more challenging to calculate with than positional systems, in particular, because the former offer fewer opportunities to perform some parts of the calculation externally, while the latter allow, for example, for carrying numbers. By contrast, nonpositional systems provide straightforward, visual representations of quantity that positional systems lack. For example, one can see at a glance that XXXIII is larger than XII, whereas a user of Arabic numerals needs to retrieve the values of 1, 2, and 3 from memory to assess whether 33 is larger than 12.

Improving Conceptual Stability

Creativity involves a complex manipulation of conceptual structures. These need to be represented in such a way that some parts of the representation can be altered (e.g., combining new ideas with old ones) while at the same time keeping other parts unaltered. For instance, the available physical space where an architectural solution needs to be implemented typically remains unchanged regardless of the solution that carries the day. Hutchins (2005) notes that the complexity of creative tasks can be greatly increased if the stability of the representation is improved. One obvious way to increase conceptual stability is to simply carry out creative solutions in the real world instead of representing them mentally. Painters, for example, often test different compositional ideas on their canvas by lightly outlining them (as x-rays of historical paintings indicate), or even by altering their design while the painting progresses (the older layers with earlier solutions, the so-called *pentimenti*, are sometimes still partly visible). This allows them to accurately assess the effects of compositional alterations. Also, they typically do not mix colors mentally, but directly test different color combinations on their palette. When reasoning about features of the environment, it is often cumbersome and suboptimal to make an internal, mental representation of them. When testing compositional ideas in the mind, it is difficult to keep some elements unchanged while altering others. By using the external representation as its own best model, a designer can directly interact with it, making her thinking easier, faster, and more reliable. Because they do not involve internal reconstruction, such real-world interactions with the environment are less liable to error.

Making Hidden or Nonobvious Properties More Explicit

Although the world is often its own best model (Brooks 1991), it is not always possible to rely on direct interactions with the world to solve creative problems (e.g., in architectural or airplane design). Moreover, making a new external representation of some features of the world sometimes reveals properties that were hitherto hidden or nonobvious. Kirsh (2010) provides the example of visual designers, who shift between scale models, pen-and-paper diagrams, computer-generated fly-throughs, and various other media. By making multiple representations, they discover structural properties that were previously undetected. A 3D model allows engineers to approach the design from different angles. By observing it from unusual viewpoints, they can see structural relations and detect violations of constraints that would not be detected otherwise. Scale models have the advantage that their relations logically and physically are independent from the designer. Unlike a mental representation, an actual physical model needs to be self-consistent. It can be examined and manipulated independently of the designer's prior ideas and allows for discussion, since its structural elements are there for all to see. Pen-and-paper diagrams do not allow for such rich and detailed inferences (especially not the multiple angles), but allow one to keep a sense of the big picture, the basic ideas underlying the design. Fly-throughs, on the other hand, can give one a phenomenological impression of what the design would look and feel like once executed.

Providing a Handle on Concepts That Are Difficult to Grasp

Not all ideas are equally easy to comprehend and handle. Cognitive anthropologists have examined how the structure of the human mind influences the way we acquire and transmit ideas. Consider a child who learns that a platypus is an animal. From this information alone, she can rely on a rich body of knowledge she already possesses: she can infer that platypuses need food and drink, can reproduce, will die, and so on. The concept platypus is thus a relatively easy concept to learn.

One cannot rely on this earlier-stored tacit knowledge for all concepts. Few people have a good grasp of quantum mechanics or relativity theory, because both run counter to our commonsense conception of physics. Even a concept like heliocentrism is difficult to represent, as is clear in people's inability to solve problems such as why there are different seasons. Most laypeople think it is because the Earth is closer to the Sun in summer than in winter, but realize this cannot be correct, since this does not explain why seasons differ between geographical locations. External representations, such as a model of the solar system that clearly indicates the eccentricity of the Earth's orbit, can facilitate this. Without external representations, some solutions to cognitive problems are almost literally unthinkable. For example, mathematical solutions like algebraic rules to solve second- and higher-degree equations would be impossible without some way of representing these problems externally, either through symbols, as in western mathematics since the sixteenth century, or diagrams, as in ancient Greek and medieval Islamic mathematics.

Costs of Epistemic Tool Use

Epistemic tool use clearly provides many cognitive benefits, but may also carry cognitive costs. In a world where large chunks of information can be stored and transmitted with high accuracy, thanks to its external storage and where diverse channels can be used to transmit these, people can have too much information pushed at them, resulting in a cognitive overload as irrelevant data do not get filtered out. This problem, however, is not so much caused by the amount of information but, rather, by lack of control over it. Employees who return to work from an extended holiday are typically confronted with a large pile of paper mail and dossiers, an overflow of unanswered e-mails, and recordings of missed phone calls. All this information must at least be sifted through in order to decide whether and how to respond, causing stress and anxiety.

Potential cognitive costs not only present themselves for information that is provided but also for information one can freely retrieve. Take the so-called Google effect on memory. In a series of experiments, Sparrow et al. (2011) presented participants with a large set of trivia they had to type on a computer. Half of the participants were told they could use the computer to retrieve facts later on; the others were told the computer would erase the typed information. Participants who thought that they could not rely on the typed notes showed a superior recall. Those who were deceived into expecting they could use the typed notes recalled the information poorly. In a variation on this experiment, Sparrow et al. (2011) let students type information in several folders on a computer. Again, the subjects who were led to believe that they could retrieve the data later on were less good at recalling the facts they stored. Strikingly, they were better at remembering where it was stored than at recalling the information itself. The widespread use of search engines and digital storage thus alters the way human natural memory functions: people shift from recall of facts to recall of where these facts are stored. This in itself may not be a problem, but it can become a problem if information becomes temporarily unavailable, or gets accidentally destroyed (e.g., hard drive failure). As the authors were finishing this entry (January 19, 2012), there was a blackout of Wikipedia, causing disruption and frustration among students and redaction rooms worldwide.

Theoretical Background and Open-Ended Issues

Material culture plays an indispensable role in human reasoning processes. There are several theoretical models to describe how material culture accomplishes this: internalism, active externalism, and cognitive integration.

Internalism

Internalism is the standard view in cognitive science. It maintains that although epistemic actions play an important role in improving our cognitive capacities, they are not genuinely part of cognitive processes. Internalists think that cognitive processes are as a matter of fact purely intracranial, that is, they only take place inside the skull. An analogy with pragmatic tool use, offered by Adams and Aizawa (2001), illustrates this. A person who uses lopping shears to cut thick branches is accomplishing something he would not be able to do with his bare hands, but this does not imply that the muscular processes within his hands and arms actually extend into the shears. Similarly, although microscopes and diagrams are involved in our epistemic actions, this does not imply that one should attribute cognitive agency to these objects. Some authors writing in the field of extended cognition (e.g., Menary 2007) have criticized internalism because it places severe constraints on what counts as cognitive. Obviously, creative reasoning also relies on internal cognitive processes, such as when one makes a chain of associative thought or when ideas one has previously been "brooding on" combine to yield a sudden insight. However, as outlined in section "Extended Cognition: Key Concepts", without external media, creative solutions would be highly constrained, not only in their complexity (purely internal mental representations are hard to stably keep in memory), but also in their kind (some creative solutions are literally unthinkable without external representations). Hence, internalism does not seem to be a fruitful theoretical model to explain what goes on in creative reasoning.

Active Externalism

Active externalists think of cognition as a coupled process, where internal cognitive operations causally interact with epistemic actions. For example, multiplying two numbers using pen and paper consists of internal cognitive processes (e.g., mental arithmetic) coupled with external cognitive processes (e.g., carrying numbers, writing down results). A possible worry is that by granting cognitive status to epistemic actions, one might overextend cognition to every object that is somehow causally involved in cognitive processes. Do a pencil and notepad become part of cognition because these objects were used in a cognitive task? To adjudicate which instances of epistemic tool use are cognitive, Clark and Chalmers (1998) propose the parity principle. Roughly, this holds that if one characterizes a process that takes place in the brain as cognitive, one also ought to characterize a structurally similar process that takes place outside of the brain as cognitive. Take an Alzheimer's patient who relies on a notebook to keep track of facts and appointments: if one is happy to concede that the neurologically normal person is informed by her (internally stored) beliefs about facts and appointments, one should, according to Clark and Chalmers (1998), also regard the externally stored information in the notebook of the Alzheimer's patient as beliefs and thus treat his use of the notebook as cognitive.

Cognitive Integration

Although the parity principle may be useful to overcome some traditional ways of thinking about cognition, it is quite limited when it comes to describing what actually goes on when one is engaged in epistemic tool use. Indeed, in many cases, thinking with the help of external media is radically different from thinking in a purely internal way. An engineer who engages in real-world interaction with a model or pen-and-paper diagram is thinking in a very different way compared to one who ponders about his design using mental representations only. The real-world interactions allow for more consideration of details and can bring to light properties that remain undetected when engaged in internalized cognition. Thus, some authors (e.g., Menary 2007) have argued that the parity principle may not be a good starting point for thinking about extended cognition. Cognition should not be limited to those instances of intracranial processing and external actions that happen to be isomorphic to them, but rather, cognition should be conceived of as an integration of internal and external processes. This involves a causal, dynamic interaction between both types of processes, where the practices of manipulating external objects can lead to structural changes in the way internal cognitive processes take place. The Google effect on human memory, where an increased reliance on the Internet and other external sources has altered internal memory processes, provides a good example of such integration.

Practical Applicability of Extended Cognition Research for Creativity and Innovation

This entry of the extended cognition literature indicates that humans rely on material culture to perform a variety of epistemic actions. These are not merely duplicates of internal cognitive processes but are often structurally very different. Although the extended cognition literature is at present mostly concerned with describing how material culture enhances human cognition, one can draw some practical conclusions for its role in human creativity and innovation. As reviewed here, epistemic actions provide a handle for ideas that are difficult to keep in mind; they allow one to detect properties that are not obvious and improve conceptual stability. Given that different external representations facilitate diverse solutions, creative workers frequently use disparate media to work on the same problem. The chance that an undetected problem or unconceived solution becomes apparent increases as one uses different ways to externalize the problem one is working on. However, engaging in epistemic actions does present a cost in terms of time, energy, and resources. Using a new software program can provide benefits, but requires an initial learning period before these become apparent. Developing external representations (e.g., scale models) requires time, money, and energy. Individual reasoners will therefore have to make trade-offs between what they are willing to invest in the development of external representations that aid their cognitive processes (e.g., make a computerized fly-through or a scale model) and the expected payoffs of this in facilitating or promoting creative solutions.

Since humans have access to a variety of epistemic tools to an unprecedented extent, innovators will need to consider carefully when deciding which tools they will use. For tasks that require creative solutions, it seems important to choose external media that:

- Help to lighten cognitive load, so that more attention and cognitive resources can be devoted to envisaging new solutions
- Enhance conceptual stability, which allows one to consider more complex problems and to develop more true-to-life solutions
- Bring to the fore features that were previously undetected, increasing the pool of possible creative solutions
- Allow to represent ideas that are hard to conceive internally, expanding the range of novel ideas that can be applied in problem solving

Conclusions and Future Directions

The role of material culture in human reasoning, especially in tasks that involve novel, creative solutions, is substantial and unavoidable. Coming up with creative solutions would not only be more cumbersome and labor-intensive – without epistemic tools, some solutions would just be unthinkable. Recognizing the importance of epistemic tool use for creativity highlights the importance of choosing good external representations. Sometimes, the world is its own best model, but in many cases, innovators need to develop new external representations to solve creative problems. By choosing the right epistemic tools, one can facilitate creative discovery to a considerable extent.

The cognitive study of the use of material culture can benefit significantly from a closer look at real-world examples, and this is an important direction where future research can be carried out. Until now, a large part of this literature has been concerned with in vitro psychological studies that take place in the laboratory, where the available epistemic resources are highly restricted (e.g., Kirsh and Maglio 1994; Sparrow et al. 2011). Next to this, mostly theoretical and philosophical considerations play a role (e.g., Clark and Chalmers 1998). Examining the actual practice of creative individuals like engineers or architects at work in R&D departments or design studios can bring to light *what* informs the choices made by creative individuals about *which* epistemic tools they will use. Such in vivo psychological studies have up to now mainly been conducted in science labs and military settings (see, for instance, the work of Bruno Latour, Kevin Dunbar, and Edwin Hutchins).

Studies like these can shed light on what drives real-world creative work and the role of epistemic tools therein, for instance, trade-offs between time and money constraints and the advantages of epistemic engineering.

Cross-References

- ▶ Adaptive Creativity and Innovative Creativity
- ▶ Cognition of Creativity
- ▶ In Search of Cognitive Foundations of Creativity
- ▶ Invention and Innovation as Creative Problem-Solving Activities
- ▶ Research on Creativity

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