Whorf versus Socrates, round 10

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A recent paper by Dehaene, Izard, Pica and Spelke examined geometric concepts among the Munduruku, an Amazonian group without many linguistic terms for spatial relations, and without maps or formal schooling. Their profile of strengths and weaknesses provides new insights into the nature of the human mind and the importance of culture and language to the development of thought.

What makes us human? Our species has many distinctive characteristics, including our mode of locomotion, our lack of tails, and the structure of our jaws, teeth and throats. But most people do not think about tails, teeth, or throats when they ponder the question of human nature. Our species' crowning glory seems to most of us to be our minds, which allow us to make tools, plan for the future, and to speak to each other. These functions seem key to our evolutionary success. However, despite widespread agreement on the power of the human brain, there are many interpretations of the nature of human cognitive ability. One line of thought suggests that we are smart because we are good general data crunchers, capable of extracting pattern from great amounts and wide varieties of input [1]. Naturally linked to this point of view are the propositions that our long period of childhood enables us to spend a lot of time learning the accumulated wisdom of our elders [2], and that language is essential to cultural transmission of past cognitive achievements [3] and indeed, to thought itself, as famously suggested by Benjamin Whorf [4]. An opposing line of thought sees the human mind as 'massively modular' with specific representations of the 'core knowledge' required for language, mathematical thinking, and spatial reasoning that are either innately present, or extracted from naturally-occurring input with minimal effort by evolutionarily-prepared minds [5]. This position can be traced back to Socrates (or, at least, to Plato's account of Socrates' thinking). In a recent set of studies with the Munduruku, a group of indigenous Amazonian people, Dehaene, Izard, Pica and Spelke have given us reason to see Socrates as leading on points in his match against Whorf [6]. Their results also hint, however, at ways in which Whorf might have scored a few points, although these aspects of the data are, regrettably, not stressed by the authors. Perhaps best of all, the Munduruku data suggest that *both* of the opposing points of view in this long-standing debate may be too extreme.

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What the Munduruku know about geometry

The Munduruku live in isolated villages and have little access to schools. They speak a language that is reported to have few words for geometric or spatial concepts (although this matter may need more extensive evaluation), they do not possess instruments such as rulers or compasses, and they apparently do not use or draw maps extensively (although they do occasionally draw maps and one would like to know more about this matter). Thus, if cultural transmission and linguistic communication were essential to the formation of basic spatial concepts, as Whorf thought, Dehaene *et al.* argue that the Munduruku would be expected to perform poorly when asked about such fundamental concepts as parallelism or congruence. On the other hand, if the human mind comes equipped with the prerequisites for spatial thought, they would be expected to be able to recognize such concepts. Along similar lines, Socrates is famously reputed (by Plato) to have elicited sophisticated concepts from an untutored slave boy through patient questioning.

Dehaene and his collaborators evaluated spatial thinking among Munduruku children and adults using two clever techniques. One probe involved showing participants panels of six figures (using a solar-powered laptop). Five figures shared a key geometric characteristic that the other one lacked. For instance, there might be five pairs of parallel lines and one pair of lines that did not run in parallel. Crucially, the five sets of parallel lines varied among themselves in several ways, such as their orientation and the distance between the paired lines, as shown in Figure 1. When asked to point out the 'weird' or 'ugly' stimulus, the Munduruku reliably chose the geometrically odd figure, such as the non-parallel lines, as predicted by the 'core knowledge' position.

This test might be claimed not to tap higher-level reasoning, and so the authors conducted a second experiment to provide converging evidence. They asked their Munduruku participants to perform a mapping task that involved three containers arranged on the ground with an object hidden under one of them. Participants were given maps that showed the layout, with a star indicating which container held the hidden object. Whether one of the containers was distinctive was varied, as well as what shape the three containers formed and how the map was aligned with the represented array. In all cases, the Munduruku retrieved the hidden objects at levels above chance.

Socrates in a knockout?

The results we have just discussed seem to show strong support for Socrates, and for the hard-wired view of human cognitive ability. This aspect of the paper was heavily

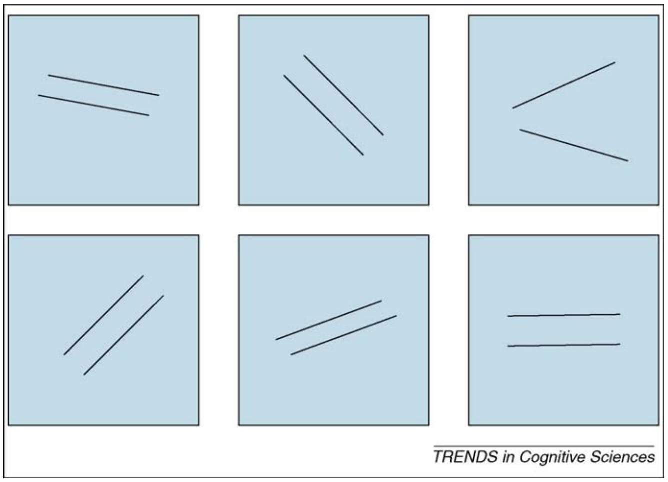

Figure 1. Participants are asked to select the image that does not belong from a set of six images. This stimulus set was used to test core knowledge of the idea of parallelism. Adapted with permission from Dehaene *et al.* [6].

stressed in media coverage of the study by outlets such as *ABC News* and the *New York Times*. However, various aspects of the data will require further empirical exploration and debate (e.g. definition of chance performance in the map task). Even without such information though, it is worth emphasizing that some aspects of the current dataset actually *support* Whorf's position that culture and language are crucial for full development of our geometric and spatial potential. Dehaene and his colleagues tested American children and adults as a comparison group for their Amazonian sample, and they repeatedly found that American adults did better than Munduruku of any age, as well as better than American children. It is true that correlational analyses showed similarities across groups in which tasks were hardest, as the authors stress. However, they should also have placed some emphasis on the fact that American adults coped reliably better with the hard tasks. This improved performance shows us that something about culture, language or education likely helps us build a more robust edifice on the foundation of our core intuitions. The Munduruku performed particularly poorly on items involving geometric transformations, and the fact that American adults can cope with such items is noteworthy because it is likely of practical importance to performance in science and technical disciplines. Skill levels in mental rotation may depend critically on environmental input and practice [7].

A new opponent?

Whorf stressed the role of language in thought. However, there are other ways to conceptualize how the human mind might rely on environmental input. Recent proponents of the importance of environment to cognitive development point to the possibility that our abilities depend on 'expectable' input [8]. Every ecological niche that humans occupy can be expected to contain physical objects that move according to physical laws, for example. Humans learn spatial knowledge through experiences that we all share, such as reaching, crawling, and walking [9]. And, in fact, Dehaene *et al.* also note, though they did not test, that it is possible that the geometric intuitions they assessed are acquired progressively during the first 6 years of life, i.e. at ages younger than those they studied. Finer-grained study of geometric intuitions and mapping ability in Munduruku infants and very young children might show a progression of success, as has been found in previous studies of American infants and preschoolers, who often do *not* seem able to cope with some of the concepts for which the older American and Munduruku children showed success [10,11]. Put simply, the article gives short shrift to the critically important developmental question of how nature and nurture interact to produce adult abilities.

Beyond the boxing analogy

The study of the human mind has been increasingly enriched by interdisciplinary perspectives and methods. Dehaene *et al.* have made good use of the common ground between cognitive psychology and cognitive anthropology, but there are also burgeoning collaborations across species lines. Recent work, some of it by Elizabeth Spelke, a co-author of the Munduruku study, has shown us that a wide variety of non-human animals use geometric information to reorient in their spatial surround [12]. Spelke and her colleagues have argued that human language plays a crucial role in how humans supplement geometric information with other useful information [13] although there are doubts about this conclusion [14]. This line of work, combined with the Munduruku dataset, thus offers several exciting challenges. First, we are invited to clarify the nature of the geometric intuitions that we may share with other species. It is possible that Dehaene *et al.* have not shown us what is distinctive to human nature, but rather what is shared across species, perhaps some as humble as invertebrates, who also must find their way around in the world. Second, we see that we need to think very precisely about what language does and does not help us to do in the world. Our ability to communicate may be crucial for some tasks, helpful though not necessary for others, and irrelevant in yet other situations. Further work on the language of the Munduruku may be illuminating, and analysis of what happens in American schools that creates high mean levels of performance is needed too. Third, we need to delineate why and how some of the core abilities that all humans have come to be developed to different degrees in ways that depend on interactions of SES and gender [15]. Such group differences also speak to the relevance of the environment.

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Letters

The missing whole in perceptual models of perirhinal cortex

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The possibility that perirhinal cortex (PRh) plays a role in perceptual processing of objects, in addition to its well-established memory functions, has produced a growing body of research that was recently summarized by Buckley and Gaffan and integrated in their 'levels of representation' (LR) thesis [1]. The most important new experiments reviewed probed the ability of PRh-lesioned primates (human and non-human) to make perceptual discriminations in the presence of minimal memory demands. They were conducted to counter the criticism that the impairments previously observed in concurrent discrimination learning (CDL) might reflect mnemonic rather than perceptual difficulties (e.g. [2]). The new evidence discussed in support of a perceptual role for PRh was obtained with oddity tasks, morph tasks, and a re-analysis of the first trials of a CDL task involving viewpoint generalization. These tasks differ from the original CDL tasks, however, not only with respect to memory but also perceptual demands. First, they require judgements of graded similarity instead of exact matching. Second, successful performance hinges upon perceiving holistic gestalt properties of objects. These perceptual demands raise concerns whether the involvement of PRh in perceptual discriminations can be accounted for by the mechanism described in Buckley and Gaffan's LR thesis.

The LR thesis holds that PRh is recruited in tasks, perceptual or mnemonic, that require discriminations of similar objects. PRh overcomes the 'feature ambiguity' [3] that is inherent in anterior inferotemporal (TE) inputs by representing conjunctions of features that are individually insufficient to allow for unambiguous object identification. Put another way, PRh performs pattern separation on overly similar object representations in TE. In the perceptual/mnemonic feature conjunction (PMFC) model that Buckley and Gaffan cite to elaborate on the computational implementation, PRh units are narrowly tuned to prefer a close match with a unique collection of features that represent a specific object [4]; avoiding generalization among similar inputs is the key to how the model resolves feature ambiguity. With such an architecture, however, it is difficult to explain why the integrity of PRh is crucial on tasks that entail stimulus generalization and judgments of graded similarity. Successful performance in many of the studies reviewed required subjects to generalize across changes in viewpoint of objects or across changes introduced by morphing. Such changes transform an image in nonlinear ways and can occlude salient object parts from view; the only features that persist unchanged and that observers can reliably use to recognize the same object after it has been transformed are higher-order gestalt characteristics. In the PMFC model, however, PRh does not represent the gestalt of stimuli. What is represented, instead, is a linear combination of the features, that is, a literal sum of the parts. In general, a representation that is simply a list of which features combine to define an object is not a gestalt [5].

The LR thesis also appears to be at odds with evidence on the neural coding scheme in PRh. The general idea of feature conjunctions and the specific architecture of the PMFC model imply a sparse local system in which a neural unit responds to only one or a few input patterns, while being unresponsive to other similar patterns. This principle contrasts with the notion of coarse distributed coding, in which an object is represented by the joint activity of many units, and in which each unit responds robustly to many different patterns. Recent evidence obtained with single-cell recordings suggests that primate PRh neurons do indeed use coarse coding [6]. Visually selective PRh neurons were found to be broadly tuned and were *more* coarse (i.e. less selective) than TE neurons [7]. This evidence is difficult to reconcile with the LR thesis.

Coarse coding would in fact make for an efficient scheme for the representation of objects in PRh. Responses of coarse-coding neurons as a population can distinguish between similar inputs, and unlike responses in sparse-coding systems, they are graded: the similarity of the responses reflects the similarity of the input patterns.

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