How did we get so smart?

A comment on "Homo informatio" by Michael J. Walker

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In "Why we're so smart" (2003), Dedre Gentner argued that the distinctive cognitive capabilities of humans rest on three fundamental pillars: 1) reasoning and learning by analogy, 2) symbolic language, particularly relational language, and 3) the ability to combine these two [1]. Michael Walker's "Homo informatio" asks, in effect, how we got there. Walker argues that networks of small groups, loosely related by kinship, mostly cooperative, and inhabiting a challenging environment, provided a setting in which the Baldwin effect [2] could gradually increase the human zone of bounded surprisal (ZBS), the extent to which unexpected events can be recognized as interesting enough to learn from [3]. He suggests, in other words, that it is the capacity to pay attention to novelty – particularly unthreatening novelty – that natural selection gradually increased in the lineage leading to us, and it did so because our ancestors' niches both provided unique opportunities and imposed unique requirements to do so.

What, however, is the mechanism of ZBS expansion, and how does natural selection get a grip on it? Heritability in examined cognitive traits is highly multigenic [4,5], so the likelihood of an as-yet undiscovered "ZBS gene" seems low. It is more plausible that natural selection acted on heritable neuroarchitectural structures or functions that, consistently with the Baldwin effect hypothesis, implement behaviors associated with curiosity, attentiveness, and learning.

Here Gentner's paper may provide some clues. Analogical ability increases the scope of what can be seen as relevant to a given situation, and wider relevance corresponds to wider salience. Screwdrivers start to look like hammers, for example, when pounding something is required. Having ways to communicate relations, whether formalized in language or not, allows information about, e.g. cause and effect to be transferred. Teaching a novel idea or skill by analogy to an idea or skill already mastered can make learning much more efficient. Structures or functions associated with analogy and the representation of relations may, therefore, be good candidates for involvement in ZBS implementation, and hence good candidates for evolutionary "knobs" accessible to natural selection.

Analogical reasoning using language is, as far we know, restricted to humans. Tool improvisation, however, has the inferential structure of analogy [6]; indeed it matches the canonical structure-mapping form developed to model verbal analogies [7]. Animals across a broad phylogenetic range, including some invertebrates, have by now been observed to improvise tools [8]; hence the neuroarchitectural underpinnings of structure mappings that involve coordinated bodily motions are phylogenetically deep. As Walker points out with respect to hominid tool-use, learning how to make or use a tool from others requires receptivity to novel information, i.e. a suitable ZBS. The broad range of animal tool cultures [9] indicates that such receptivity is not limited to hominids.

Tool-making and tool-use demonstrations convey relational information, specifically cause-effect information. They also convey higher-order information about the structure of action episodes: that many different motions, in a particular order, are generally required to achieve a goal. Motile animals know this implicitly; tool-use demonstrations makes this relational information explicit. Complex social demonstrations, if they are attended to, also do this. From this perspective, learning about the social world and learning about the nonsocial world may not be as different as sometimes assumed [10].

Stephanie Theves has recent proposed a neuroarchitectural version of [1], proposing that hippocampal-entorhinal relation abstraction and fronto-parietal structure mapping are the architectural cores of human intelligence [11]. If this is correct, selective pressure to increase hippocampal-entorhinal function – e.g. to maintain detailed metal maps of surrounding terrain, or to accurately identify many different individual objects – or selective pressure to increase frontal-parietal coupling – e.g. to improve tool improvisation or social-role learning – could be expected to drive ZBS expansion. Indeed, it suggests that ZBS expansion, at least in humans, corresponds to an increase in receptivity to relational information and analogies.

It is at least plausible that selective pressure to increase hippocampal-entorhinal function and frontal-parietal coupling could have a secondary effect: increased elaboration of the default-mode network (DMN). It is commonly held that the same theory of mind (ToM) capabilities are applied in modeling the self and others. The idea that something has a "mind" is, in this case, fundamentally an analogy, with "mirroring" fundamentally a structure mapping; the mirror network [12], from this perspective, is an agent-specific analogy machine. It is not a large functional generalization from ToM to the conscious imagination of counterfactuals, the canonical function of the DMN [13].

These considerations bring us back to Walker's focus on the paleohuman niche. Selective pressure for enhanced cognition could only exist in a cognitively-demanding environment, one that migrations through thousands of kilometers of diverse, often difficult, unfamiliar territory – Steven Pinker's "camping trip that never ends" [14] – surely provided. Diverse, attentive interactions in a small group, mixed sex and mixed age setting would provide plenty of relevant content. Learning in such a setting, however, much less the presumably slow dawning of useful imaginative cognition, would have above all else required relative safety. While as Walker puts it, "false dawns" may have been frequent, the niches of many our ancestors must have been relatively safe. It was this safety, I would suggest, that gave us the chance to become smart.

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