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NATURAL AND ARTEFACTUAL LANGUAGES: A MECHANISM FOR CULTURAL EVOLUTION

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ABSTRACT

Natural language provides a mechanism for cultural evolution by ensuring the persistent heredity of variations in both cultural information and information about its own construction. In the process, it not only facilitates but also limits our thinking to the ways its vocabulary and structures make possible. But the human capacity for metarepresentation frees cultural information from the restrictions of any one medium or language, and has also propelled the evolution of artefactual languages, which provide evolutionary mechanisms for specialist areas of culture. And cooperation between diverse cultural specialists can stimulate further, innovative competition between the cultural information that they share.

Debates continue about the extent to which non-human species are capable of using language or tools, of learning from each other and possessing what might be called a culture; but incontrovertibly no other species has developed anything like the depth and breadth of human culture. How has what we humans learn from each other become so much more complex and diverse than what members of other species learn from each other? It is obvious that genetic evolution can offer only a partial account. Although we can look for biological explanations of how humans came to be capable of culture, it is clear that cultural change far outpaces genetic evolution. The theory of cultural evolution says that what we need, in order to explain human culture, is a new kind of evolutionary theory: one in which the same general laws to which Charles Darwin pointed are still at work, but in a different jurisdiction. This paper provides an overview of the thesis that human languages—both natural and artefactual—provide the mechanism for cultural evolution, by enabling humans to receive and transmit variations in cultural information and resources.

Heritable Information

Evolution is a gradual, inter-generational process of change in a population's characteristics, and cannot happen unless variations in that population's characteristics are inherited across many generations. Our knowledge of biology indicates that we can usefully describe this process in terms of the *information* that inheritance mechanisms make available to each generation.

Information theory has its origins in a mathematical model of communication (Weaver 1949), a simple version of which enables us to express our understanding of inheritance in informational terms: information is inherited when one generation acts as a source, which transmits a signal to the following generation, which interprets the signal and reacts to it. This model provides a helpful starting point for our understanding of inheritance, because it emphasizes the importance of both source and receiver for the transmission of information.

But there is a weakness in this kind of "postal metaphor" (Chandler 1994) of communication, in which the source sends a package of information to a receiver: it encourages us to think of the source as actively determining the meaning of the message, and the receiver as a passive target. In reality, of course, there are multiple ways in which a receiver can interpret information. Decoding will not necessarily be a mirror image of encoding, and different receivers may therefore take different information from the same source. The receiver plays a much more active role in the communication of information than is sometimes acknowledged, and an improved theory of inheritance will rest on a better understanding of the ways in which receivers interpret and respond to information.

So, what is it that enables a receiver to interpret and react appropriately to a particular source? Each receiver must somehow be prepared to produce *this* reaction when it encounters *that* information; and the simplest way to account for the link that the receiver makes between incoming information and consequent behavior is to refer to it as a representation.

More specifically, the receiver must be in possession of a *discrete* representation. "Discrete" in a statistical sense means that a variable's values are consecutive rather than infinitesimally close. A continuous variable, in contrast, has a continuum of possible values: there are no gaps between members of a continuous set. And the crucial point here, as Eric Dietrich and Arthur Markman (2003, p. 101) have shown, is that "A system cannot discriminate between two external, environmental states with one, single continuously varying representation." In order to distinguish between two points on a continuum, S1 and S2, the system needs to categorize these different inputs: it must somehow elide "the continuous infinity of intermediate states" between the two points, by forming representations that "chunk all the states in some neighborhood of S1 with S1, and all the states in some other neighbourhood of S2 with S2." This means that the system is unable to discern the difference between inputs that are all in the right neighborhood, even when they do in fact differ from each other; but "the benefit of losing information from continuous representations is the production of a set of discriminating, potentially referring, discrete representations that are combinable" (Dietrich and Markman 2003, p. 112). In contrast, a system with one continuously varying representation is not able to discriminate between different environmental states.

This point is helpfully illustrated by picturing one of the rotary switches that can still be found in some electro-mechanical central heating time controls. These programmers have a dial that acts as a clock: it is marked from zero to twenty-four, and as it rotates the numbers pass a marker whose position indicates the current time. In addition to this fixed marker, there is also a pair of moveable tappets, which act as on or off switches. One tappet can be positioned to the time that the heating is to be switched on, and the other to the time that it is to be switched off; and in fact there is usually more than one pair, so that the heating can be switched on for more than one period of each day. The dial is a continuously varying representation of the time of day; but if that were all the system had, then it would have no means of linking the dial's position with the appropriate action. The tappets enable the system to extract, from the continuum of infinitesimally close dial positions, a number of mathematically discrete chunks, between which it can discriminate. It still cannot discriminate between two different dial positions that fall within the space between two tappets, because it has effectively elided all the positions between tappets into chunks labelled "on" or "off." But without the chunking process, it cannot discriminate between *any* of the dial positions.

This example illustrates both how discrete representations may *supervene* on continuous ones, and the crucial *functional* role that they play in enabling a system to discriminate and respond to different environmental states. The tappets are discrete representations of particular times of day, which supervene on the dial's continuously varying representation of the continuously changing time of day, enabling the system to categorize particular dial positions in order to link them to the appropriate action. Notice also that the tappet positions can be varied, in which case the system will alter its categorization of the dial's continuously varying positions; but without the tappets (discrete representations) the system could not link the dial positions to any appropriate actions.

Similarly, a human might have a continuously varying representation of the smell in a restaurant, the state of the weather or the sounds in her garden, but she will only *identify* a particular food, or the likelihood of rain, or a particular bird, if she also has a discrete representation of the relevant smell, cloud pattern or bird song. Computer scientists measure information in *bits*—binary digits—because in order to have any information at all, we must be able to differentiate between at least two possible states. And when what we detect is a varying continuum, we are effectively in receipt of only one state. Discrete representations are necessary for any receiver to link variations in a source to the appropriate variations in its response: a receiver that cannot discriminate between variations in the continuum of incoming information cannot receive any information from it.

Representational Systems

In the case of a more complex source, like variations in the marks of a script or notation system, a receiver will need to possess not just a single link between a source and a reaction, but an interrelated web of links between a range of sources and the appropriate reactions: a whole system of representation. In order to receive information from any source, we need to be appropriately prepared, and in this case, it is knowledge of the relevant *representational system* which prepares us to discretize the source, interpreting and reacting to its informational variations.

For this reason, representational systems introduce a whole new level of reliability and transgenerational persistence to the inheritance of any information or resource. We have already seen that the role of the receiver is far from passive: information may be decoded in a variety of different ways, so that the same information source can provide different information to receivers who are using different methods of interpretation. This means that if the source is non-representational (like an artefact or observed situation), having no fixed representational content, then although information can be acquired from it, different receivers may acquire different information, depending on how each one represents it. If the source is representational, however, then receivers have much less room for maneuver. Although very little information can be gleaned from a representational source by a receiver that lacks knowledge of the relevant representational system, nevertheless if we do have knowledge of the relevant representational system, then this knowledge will go a long way towards matching the information that we receive with the representational content of the source. Thus, representational content is more persistently and reliably heritable than the information that receivers might acquire from other, non-representational sources. Indeed, so long as there is a population of receivers that share the relevant representational system, its representational content is guaranteed an inheritance mechanism.

Evolution in any sphere results from the persistent heredity of variations. What has emerged here is that each generation can only receive and respond to variations that it can discretely represent. Information's inheritance is therefore dependent on the representational capacities of each generation of receivers: for any given inheritance mechanism, we need to understand not only how it transmits information, but also what enables the next generation to interpret and implement the variations in the information it receives.

We can see this in the mechanisms of cell division. When a cell successfully divides, the information that it contains in DNA is (mostly) faithfully reproduced in the same language and format; but this information could not be expressed if the cellular machinery for its transcription and translation were not also reproduced. DNA's expression depends, like any other representational system, on the existence of a receiver for the information that it carries: a receiver that knows the system. The mechanisms of cell division provide an effective mechanism for biological evolution because they ensure the persistent heredity not only of patterns of DNA sequences, but also of the cellular decoding mechanisms that are necessary for their interpretation and expression. Variations in expressed traits may result not only from variations in genetic information or in the environment, but also from epigenetic changes in the ways in which the cellular decoding mechanisms interpret that information: a reminder that, as emphasized above, decoding will not always exactly mirror encoding, and different receivers may therefore take different information from the same source.

Linguistic and Cultural Inheritance

To recap: it is only once we ask *how* one generation is able to act as a receiver of resources from another, that the tangle of evolutionary mechanisms and driving forces begins to unravel. An inheritance mechanism that transmits only information or resources cannot, on its own, act as a mechanism of evolution: the transgenerational persistence of the variations that it transmits will depend on that mechanism, or a separate mechanism, also ensuring that each generation is able to detect and react to those variations.

In human culture, while information is of course transmitted via a variety of mechanisms, including observation and imitation, it is language use that provides information's predominant inheritance mechanism. So, we need to understand both how language transmits information between generations of receivers, and how each new generation is able to make sense of the information and resources that it receives. And this means that we need to know how human cognition is able to discretize each linguistic source. A continuously varying input, like a sound wave, might be represented continuously at an early stage of auditory processing, but higher level processing systems must extract information in chunks from this continuously varying representation, in order to produce discrete representations that discriminate between parts of the continuous input (Dietrich and Markman 2003, p. 112). Humans cannot receive cultural information until they have learnt to discretize the language in which it is represented.

How does this happen? Children are not explicitly taught language, in the way that they are later taught to read and write. They just pick it up from what is being spoken all around them: an extremely impoverished input whose content will vary enormously between individuals. Despite the apparent inadequacy of this input, children acquire intricate linguistic abilities with remarkable speed. Despite the variation amongst the input, their resulting language is (in all important respects) uniform. One of the attractions of a Chomskian account (e.g., Chomsky 2006) is that if our early language acquisition is innate, then this explains not only the speed and ease with which we pick up language, but also the uniformity: given limited English input, our language instinct will enable us easily and swiftly to produce English output, and only English output.

An alternative thesis (e.g., Hurford 2004) is that the underlying grammatical uniformity of natural languages is the result of coevolution between these languages and the human brains that learn them. As we have seen, human infants must learn how to discretize the language noises that surround them: they need to be able to spot the consistent patterns in the sounds and gestures that other humans are making. And there are plenty of patterns for them to spot, because one of the key features of human language is its *compositionality*: the meaning of a portion of language is derived from the meanings of its constituent parts and the ways in which they are put together (Szabó 2017 gives an extensive overview of the principle of compositionality). So how did our communication system evolve from basic symbol-use to the compositional syntax of modern natural language? On this alternative view, "Instead of asking what the *learner* needs to successfully acquire the target grammar, we ask what the *language* needs to be successfully acquired" (Kirby 2017, p. 122).

In particular, Simon Kirby emphasizes the role of *iterated learning* in the emergence of compositionality. Whatever one's theory of language acquisition, it is clear that "the language we speak is the result of some combination of what we individually bring to the task of language acquisition and the nature of the data we are exposed to. Equally, the data we are exposed to is the product of other individuals who acquired their language in the same way" (Kirby 2017, p. 120). Language is transmitted via an iterated learning process in which the rules governing the previous generation's language use are interpreted and internalized by the current generation, and the current generation's language use, in turn, forms the raw data on which the next generation's interpretation and internalization of language rules will be based. As the number of shared symbols increases, so there develops an intergenerational bottleneck in their transmission: of all the possible symbols, only a small subset is observed by new learners. And it is this bottleneck, argues Kirby, which forces the emergence of a compositional language: since learners are exposed to only a small subset of possible meanings during their lifetime, a language *must* be compositional in order for learners to reconstruct it from the sample that they encounter. Thus, complex compositionality does not emerge *despite* the variability and poverty of the linguistic input to which children are exposed, but *because of* it. "Languages adapt culturally as an inevitable consequence of iterated learning in such a way that over time they become optimized for transmissibility. The tougher the transmission bottleneck, the more pressure there is on language to adapt" (Kirby 2017, p. 124).

Moreover, as Kirby points out, the fact that natural language "can be reliably acquired purely through the observation of instances of its use" (Kirby 2007, p. 10) is the pivotal point at which language meets culture, for it demonstrates that language transmits not only semantic information but also "*information about its own construction*." Natural language is, in this respect, beautifully analogous to DNA, in that it provides—to receivers with the disposition to receive it—its own means of replication and interpretation.

Cultural evolution requires an adequate explanation of how a representational system, which was complex enough to carry a uniquely broad range of cultural information, could have come to be shared by all humans. When we generalize over recurrent linguistic patterns, the result is that we discretize the language to which we are exposed, in ways that reflect its existing compositional structure. We produce, in other words, a system for representing information in discrete, hierarchically combined packages. When other people hear us using the language that we have learnt in this way, they go through the same learning process. In this way, a biologically-prepared species can acquire a complex, culturally-evolved system of representational communication; and natural language's acquisition creates receivers with the capacity to interpret and implement the information that it carries.

Thus, human languages ensure the persistent heredity of any information that they carry, by bringing to human receivers both that information itself and the means of its interpretation and transmission. Natural language is not a perfect representational system. Its structures leave plenty of room for ambiguity—which we resolve with a combination of context and non-verbal cues—and James Hurford (2003) provides interesting evidence that this may be because their primary purpose is the immediate production of a signal in a system that other receivers share, rather than precise accuracy. But what matters for culture is that the evolution of natural language provided a shared representational system, which enabled users to acquire information from each other more efficiently and effectively than was otherwise possible. That it was not a representationally perfect system would, in time, prove problematic. In the meantime, once there was a supply of language-using humans to act as receivers of cultural information, their language use provided a self-sufficient mechanism for the beginnings of an unprecedented acceleration in cultural evolution.

Language and Thought

Natural language is not only a conduit for information, however: in discretizing the world in a particular way, it both enables us to acquire information that we could not otherwise access, and shapes the ways in which we think about that information. Of course, there is a level at which humans share innate, fine-grained sensory perceptions: a level at which, since we don't need language to facilitate our perceptions, language-specific categories exert little to no influence on them. But across the literature, there is increasing evidence of the complex effects of language on non-linguistic cognition or perception, even at the level of seemingly foundational properties such as spatial relations (Holmes, Moty and Regier 2017), color cognition (Regier and Xu 2017), conceptions of time (Fuhrman, McCormick, Chen, et al. 2011) and the grouping of non-linguistic sounds (Bhatara, Boll-Avetisyan, Agua, et al. 2015; Molnar, Carreiras and Gervain 2016). Of particular relevance to this paper, it has been persuasively argued that "the effects of language on cognition may arise from the interplay of verbal codes with perceptual representations" (Regier and Xu 2017).

The human brain needs to work constantly to integrate multiple sources of sensory information, within and across modalities; and since sensory perception is never perfectly accurate, there are often situations in which different sensory signals provide conflicting information about the same source. How, then, do we successfully integrate such conflicting sensory cues? "A large body of prior research" has "repeatedly demonstrated" that when humans are combining multiple sources of information relating to continuous dimensions, such as distance or size, we "integrate cues in a near-optimal fashion, weighting cues according to their reliability" (see Bankieris, Bejjanki and Aslin 2017 for a review). But there is also a growing body of evidence that human observers "combine sensory and *category* information in a statistically optimal manner" (Bankieris, Bejjanki and Aslin 2017, my italics); and language is of course a vital source of category information.

In keeping with this thesis, Terry Regier and Yang Xu (2017) argue that as the human brain works to integrate incoming information from a variety of sources, the extent to which its conclusions are influenced by language will be determined by the "cognitive control knob" of uncertainty. When sensory information is comparatively certain, even the most relevant language-specific categories will have little influence on our perceptual discrimination: in other words, if all or most details of an object or event are readily available to the senses, then "there is little missing information for language to supply, so there should be little or no effect of language" (Regier and Xu 2017). But when there is less sensory certainty, and especially when language-specific categories are the only source of information (because there is no non-linguistic representation available for the relevant information), our cognition will be much more formatively shaped by the categories that language provides. "For example, you may be thinking of an object and find that some of its details are not mentally available to you, whether because of fading memory, fatigue, or some other factor inducing uncertainty in your mental representation." Or you may be trying to recall a particular hue of green that you have seen, but your memory of it is uncertain. "In such circumstances, the mental uncertainty essentially opens the door to language to fill in some of the missing elements, and there should be a relatively strong effect of language." In the case of your uncertain memory of the hue of green, for instance, "your recall of it would be biased toward the center of the English linguistic color category in which it fell: green" (2017).

When our senses have little to offer, and our thoughts are almost entirely dependent on language categories to facilitate them, those categories will of course exert an even stronger effect on our cognition. Thus, as natural language expanded and developed, providing its users with an increasing number of language-specific categories, it will have exerted an increasing influence on the shape of their thoughts: as it enabled its users to discretize the world in new ways, opening them up to information that they would otherwise have been unable to access, so it will also have restricted them to thinking in those ways, at least about the aspects of the world that sensory perception and unaided memory alone could not perfectly represent.

Metarepresentation

But the innate skills that enable us to learn our native language also enable us to go on learning new symbols and new compositional rules throughout our lives, and to make comparisons between different linguistic systems. Comparison between two alternatives helps us to see the key features of each, and when we make these sorts of comparisons, the subject of our thoughts—the content of our representations—is not only the information that the symbols represent, but also the symbols themselves.

When we begin to reflect on the connections between symbols and their meaning, we are engaging in a uniquely human form of thought known as *metarepresentation*. Like many other organisms, humans can form mental representations of events and entities in the world. Unlike them, we can also make those mental representations the subjects of further representations; we can think about our thoughts. The ability to metarepresent is the ability to reflect on the connection between a symbol and the information that it represents: to reflect not only on the information itself but also on how we are representing it. Is it more useful, in a particular context, to use "5" or "five", "V" or "𝍸", "101" or "$\sqrt{25}$"? What difference does it make if I describe this person as "ambitious" or "pushy", "aspiring" or "power-hungry", "determined," or "zealous"? Are there emotions or experiences that your native language expresses more accurately than mine? What effect does our use of language have on people's perceptions of themselves and others? As soon as we start to ask such questions, we are metarepresenting: thinking about how we represent information; comparing alternative approaches; potentially developing new ones.

The significance of metarepresentation is that it frees cultural information from the cognitive and psychological restrictions of any one medium or language. The metarepresentational ability to transfer information between languages and media enables us not only to acquire information but also to think about the information we have acquired: to recognize and escape the impact of the information currently underlying our behavior. As a result, it facilitated the evolution of a new kind of language.

Artefactual Language

The evolution of natural language provided humans with a shared representational system, enabling them to acquire information from anyone who used that system. It was never an absolutely precise system, and nor is it limitless: its capacity is restricted by users' cognitive abilities and by the length of time available to them for learning it. Yet, despite the system's limitations, the result of natural language evolution was an explosion in the amount of information that early humans were able to trade—and there is only so much information that we can hold and manage in our brains alone; even in our collective brains.

As the quantity of shared information increased, I have shown (Distin 2011, pp. 89–106) that a new selective pressure therefore emerged. Whereas natural language had originally evolved under the *biological* pressure for a cooperative species to be able to *communicate* more effectively with each other, now there was *cultural* pressure for the shared language to be able to *represent* information more effectively. As the briefest glance at modern culture makes clear, our cognitive escape route from the restrictions of our native language has not been restricted to other natural languages. What emerged were what I have called *artefactual* languages (Distin 2011, p. 49): systems of representation such as the written word, musical notation or the conventions of architectural drawings, which are realized in objects made or fashioned by humans, and whose structures and media offer a variety of representational advantages to the cultural information that they carry.

The most obvious representational advantage that artefacts have over speech is their persistence: they increase information's longevity. Although artefactual languages do exist whose primary media are as transient as speech—for instance, the flashes or clicks of Morse code—most artefactual media offer information the culturally-adaptive advantage of *stability* (Distin 2011, pp. 107–110 discusses some of the influences on patterns of cultural longevity and replicability).

In addition, artefactual media have a far greater *capacity* than the human memory will ever have. An external representational system is almost limitless. It enables us to hold a large overall structure of information whilst simultaneously tinkering with the details, or conversely to preserve the details while surveying the whole picture (rather as a computer uses swap space: see Distin 2011, pp. 110–111). It can also provide a kind of *scaffolding* for our thinking (Clark 1998 provides an extensive overview of this concept): one of the most restrictive features of natural language is that it is represented in the serial medium of speech; but some artefactual languages (such as maps, drawings or graphs) can represent information more holistically, enabling us to represent and manipulate information in a way that the brain acting alone could never manage.

Artefactual representations can also preserve cultural information with greater *accuracy* than the spoken word. One reason is that highly repetitive information is subject to less replicative error than information that we encounter only once, and we can consult written instructions as many times as we like (Eerkens and Lipo 2007, p. 248). Another reflects a fascinating difference between artefactual and natural languages. Natural languages tend to avoid synonyms (different words that carry the same meaning) but abound in homonyms (words that look or sound the same but have different meanings). Hurford (2003) has used computer simulations to show that this is just what happens when the selective pressure on an evolving language is for more effective communication (i.e. the outward expression of meaning). In contrast, when the selective pressure is for more accurate interpretation by receivers, what happens is that languages prefer synonyms to homonyms: they often evolve several different ways of expressing the same meaning, but rarely have ambiguous symbols. And this is just what we find in artefactual languages. One of the reasons why they represent information more accurately than natural languages is that they are more likely to include several different symbols with the same meaning than they are to include a polysemous symbol. "Computer languages and command systems, for example, frequently allow aliases (alias synonyms), but often cannot handle different intended uses of the same term in the same syntactic context (homonymy)" (Hurford 2003, p. 450). Similarly, within musical notation, "there are synonyms for a note's pitch (A♯, B♭), length (♩, ♪‿♪) and expression (·, staccato), but no truly polysemous symbols" (Distin 2011, pp. 114–117 discusses this example in more detail).

Moreover, these different ways of representing the same information might all be equivalent in terms of the meaning they carry, but because they represent it in different ways, they open us up to thinking about it in different ways. For example, as Richard Feynman highlighted (1992, p. 53), different mathematical expressions of the same physical laws may be described as mathematically but not *psychologically* equivalent: they can have such qualitatively different characters that they give different clues to other laws or circumstances, leading us to a different range of new discoveries.

Finally, artefactual languages have the advantage of *detachment* from the humans who use them. In the absence of artefactual media, we cannot communicate unless we are within sight or sound of each other, for our words, like the gestures of sign languages, are a physical part of us. Artefactual media, on the other hand, can be used to transmit information between people who might never even meet. In the competition for human attention, there are clear adaptive advantages to information that finds a way of being preserved over time, conveyed over space, or transmitted over social barriers. For this reason, in the same way that natural language provides and strengthens the *social* links between members of a community, artefactual languages can provide *functional* links between people whose communities are separated by time, space or social divisions, enabling them to get things done together even when they are otherwise unrelated (Distin 2011, pp. 120–125 discusses the significance of such functional links for cultural evolution).

Artefactual Language, Metarepresentation and Culture

It is when we move from natural to artefactual language use, changing our priority from communication to representation, that our metarepresentational capacity really begins to bear cultural fruit; for it is not until we acquire alternative means of representing information that we also learn new ways of thinking about it.

The very first artefactual symbols were alternative means of representing information that had previously been carried by natural language. In mathematics, for instance, Hurford (2001, p. 10757) distinguishes between the international scientific notation that is used to represent numbers (e.g., "260") and the numeral systems that natural languages use to describe numbers (e.g., "two hundred and sixty"). Hurford points out that even though numeral systems are explicitly taught, unlike the rest of natural language—suggesting that they exist on the very fringes of what our collective mentality can manage without external props—they still precede the written scientific notation, both in language history and in individual learning patterns. What this means is that with the creation of the very first artefactual symbols there emerged two alternative ways of representing the same information: the natural language numeral systems and the scientific notation. Distin (2011, pp. 89–106) shows that as the alternative systems began to compete with each other under representational pressure, each artefactual language began to evolve towards more efficient representation in its specific cultural area. Mathematical notation, for instance, is far more compact that the vernacular: compare "260" with the explicit representation of the addition operation and the names of the powers of the base number in the more cumbersome English phrase "two hundred *and* six*ty*." It was when we started to think about *how* we were representing the cultural information that we were sharing, that we really kick-started the evolution of artefactual languages.

Since a language is a system for representing a certain portion of information in a certain medium, its structures will be shaped both by that semantic field and by its medium. The spoken natural language, for instance, is designed to communicate human thoughts in the serial medium of human speech, and its structures (phonology, syntax, and so on) have co-evolved both with that medium and with those thoughts. Characteristics that make speech particularly well-suited to the outward expression of inner thoughts include the facts that it can be swiftly produced and easily received, and that there is a pre-pubescent period critical to its acquisition, which is facilitated by a raft of innate pre-adaptations. Its co-evolution with the human brain and physiology makes it particularly well-adapted to the serial communication of the content of human thoughts. The ways in which it discretizes information has, conversely, a significant impact on the nature of those thoughts; especially on thoughts that depend for their coherence on the language in which we originally encounter them.

But artefactual languages evolved at precisely the point at which our brains' capacity to hold and manipulate information ran out of steam. Their function is to manage and indeed to facilitate the emergence of the cultural information that we cannot manage with brains and speech alone. Unlike natural languages, therefore, artefactual languages do not need to conform to rules that are innately learnable by human children. We have the luxury of learning them consciously, since we do not need them in order to communicate with each other, but only to handle information.

It is inevitable, therefore, that artefactual languages will shape our thoughts about their cultural content: each artefactual language evolves to represent a specific area of culture; and that area of culture evolves, in turn, to be conceptualized in ways that are representable by the relevant artefactual language in the relevant artefactual media. The evolution of artefactual languages vastly increases and enhances the ways in which we can think about the areas that they represent; but conversely, they also limit us to those ways. It is the power of metarepresentation that enables us to escape these limitations: we can learn not only new information but also new ways of representing it; new media in which to embody it.

This is significant because, as Robert Aunger (2002, p. 157) has emphasized, the medium in which information is stored is enormously significant for evolutionary dynamics (though note that Aunger would deny that information can be replicated across media). A poem might be printed in a paperback anthology, spoken aloud at a recital, preserved on a vinyl record or accessed via a webpage; and each version will have a different impact on the longevity and stability of the poem's preservation, the accuracy and fecundity of its replication, the potency of its emotional effects, the size of its potential audience, and so on. The system in which information is represented will impact upon a similar range of factors. The poem might be represented in spoken Igbo, in Chinese Sign Language, in written Nynorsk or even in ASCII. Each of these alternatives will, in combination with the medium in which it is realized, have a particular profile of effects on the evolutionary dynamics of the same piece of cultural information. Each language will "call forth a certain noticing" (Price and Shaw 1998, p. 189); each medium will deteriorate at its own rate. Some media, and some systems of representation, are inherently better than others at ensuring the long-term, faithful preservation of cultural information. Others have more potential for swift and extensive transmission. Each endows the information that it carries with a particular evolutionary scope, intimately connected with which are its particular evolutionary limits. The significance of metarepresentation is that it can free cultural information from the limitations of any one medium or language.

Cultural Innovation

Under evolutionary pressure to represent more efficiently, each artefactual language coevolves with both its media and its content; and we can see a similar coevolution, in natural languages, between subject-specific knowledge and vocabulary. As we acquire such specialist languages, so they prepare us to receive the cultural information that they carry, giving us access to specialist information and conceptual tools: knowledge and concepts that we could not access without the languages that support them. Yet, as we have seen, each language restricts us to a particular way of thinking about the information that it represents, and does not help us to access information beyond what it can represent. So, as subject areas evolve and specialists become more immersed in their own field, a prevailing orthodoxy can emerge, which is difficult to challenge. People who are educated and heavily invested in an existing paradigm will not necessarily welcome or find it easy to accept an innovative alternative. Douglas Renwick, Dermot Breslin and Ilfryn Price (2019) show how there can be, in effect, a selective bias against ideas that challenge the orthodoxy, especially as academics find themselves under pressure to publish in highly ranked journals, and find it easier to have papers accepted if they are working within the current paradigm than if they are challenging it.

Now, a bias towards tried and tested knowledge, methods and technology is not always a bad thing. In any evolutionary sphere, it is possible to have too much innovation. In biology, for example, species barriers between sexually reproducing species limit the amount of genetic variation in each population and protect a pool of genes, which have successfully evolved to survive in a particular ecological niche, from the risks of too much disadvantageous variation. And in culture, too, we want to be able to build on existing knowledge and protect what has been found to work. Having put our intellectual money on one theory, it makes good psychological and epistemological sense to accept new ideas only if they are either compatible with it or have obvious enough advantages over it to compensate for our wasted investment.

The problem arises when present structures protect successful past innovation so effectively that they also discourage future innovation. For example, in the context of majority support for the prevailing paradigm, Cailin O'Connor (2017) has shown how "the dynamics of social interaction between minority and majority groups—the cultural Red King effect"—can give rise to a situation in which a conceptual innovation is persistently disadvantaged, solely by dint of its minority status. At the extreme, cultural, and disciplinary isolation can cause beliefs and attitudes to become so deeply embedded that we are no longer able to see them because we are seeing the world *through* them. As If Price and Ray Shaw (1998, pp. 100–109) describe, the more widely shared a view is, the more invisible it becomes, because everyone is viewing the world through the same lens.

Thus, if a prevailing paradigm or technology becomes sufficiently dominant, then innovations may need to be nurtured in isolated populations before they can challenge the mainstream. We know from biology that isolation can be significant for the evolution of new species. In culture, similarly, technologies might first come into existence as playthings of the rich: expensive prototypes or demonstrators, made in small numbers. Conceptual innovation might be nurtured in discussion groups and small specialist journals. Existing cultural information has found an ecological niche to exploit, and if novelties are to succeed then they may need to emerge in the safety of a different niche (see Renwick, Breslin, and Price 2019).

So cultural barriers are not always bad things: they can nurture novelty and protect success. But they can also be used to defend the outdated or mistaken against competition and correction. How is a balance to be struck? The solution lies in the human capacities for both metarepresentation and cooperation.

There is extensive psychological evidence that humans are what Michael Tomasello (e.g., 2011; 2018) has called "ultra-cooperative" primates. We are not only instinctively motivated to learn the local natural language in order to access the culture and social relationships within the local group, but also capable of learning artefactual languages in order to access information and functional relationships across social and disciplinary boundaries. Indeed, Hurford (2007, p. 270) has described the very use of a shared language as a form of cooperation, in which participants assent to the use of a conventional communicative code. And cross-cultural or interdisciplinary *cooperation* between diverse cultural *agents* can lead to productive *competition* between cultural *information*.

We do need people to specialize: to acquire the language and concepts that have coevolved in a particular cultural area; to mine each area for deeper knowledge and understanding; to exploit its resources for their implications and applications.

But we also need people to take risks: to go prospecting as well as mining. We need to provide the structures and resources that will enable people to explore new areas—innovative ideas and technologies—in isolation from too much competition.

And we need to encourage people to share what they have found: to cooperate across cultural and disciplinary boundaries; to combine and recombine what has been found in each area, creating not only a new and more varied range of information, but also a greater range of skills and an increased tendency to metarepresent which together can create the conditions under which successful innovation can emerge. For it is when we encounter alternatives that we begin to make comparisons and choices: to metarepresent and consequently to innovate.

Our instinct for cooperation makes possible our use of shared languages, which prepare us to receive the information that they transmit.

Our capacity for metarepresentation enables us to keep on acquiring and developing new languages: to free information from one code or medium and re-represent it in another; to compare and recombine information across boundaries of culture and discipline, time and space. Artefactual languages, in particular, provide the evolutionary mechanism for a vast depth and diversity of specialist cultural knowledge, and they also facilitate and sustain functional relationships, through which people who have no social connections with one another can nonetheless cooperate across social, geographical and temporal boundaries, creating a conduit through which a greater number and diversity of ideas can flow into one cultural pool. To repeat: cross-cultural or interdisciplinary *cooperation* between diverse cultural *agents* can lead to productive *competition* between cultural *information*.

Conclusion

The origin of culture—the explanation of how what we humans learn from each other has become so very much more complex and diverse than what members of any other species learn from each other—lies in the inheritance mechanism that natural and artefactual languages provide for cultural information. Natural and artefactual languages ensure the persistent heredity of the information that they represent, because humans are genetically prepared to learn language from language: from linguistic input we can receive both information and the means of its interpretation and transmission. Languages thus provide the inheritance mechanism for the information that is expressed in all the complex diversity of human culture, from hedgerows, to blackberry-and-apple pie recipes, to philosophical studies of gustatory aesthetics. That is what explains how—in culture, as in nature—"from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." (Darwin 1859/1985, p. 460)

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