Mills Made of Grist, and Other Interesting Ideas In Need of Clarification

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Abstract: Heyes's book is an important contribution that rightly integrates cognitive development and cultural evolution. However, understanding the cultural evolution of cognitive gadgets requires a deeper appreciation of complexity, feedback, and self-organization than her book exhibits.

Heyes is right to bring cultural evolution to the forefront of cognitive development. As the cognitive and developmental sciences have been slowly drifting away from extreme nativist claims, the glaring question is now "where do constraints on social learning come from?" As it happens, cultural and language evolution experts have been working on aspects of this question for some time now. Heyes gives the reader a number of useful landmarks from those fields, but the real story of how cognitive development and cultural evolution interact is somewhat more complex than she implies. We unpack the book's central evolutionary arguments, noting some important perspectives that are omitted, and highlighting the need for involvement by experts in complex systems. We will also identify problems with her central grist-and-mills metaphor. Though our tone is one of critique, we want to make it clear that we think Heyes's book is an important contribution to the literatures on both cognitive development and cultural evolution, and we fully endorse her thesis that a deeper synergy between these often-disconnected research areas is paramount.

There are two principal components of Heyes's argument. The first is that cognitive mechanisms are not innate but are shaped during development by social forces—we might call this "gadgetization." The second component is that the structure of these social forces is the product of cultural evolutionary processes. We address each of these in turn.

The gadgetization that Heyes writes about is an important and underappreciated idea, with thick roots in the cognitive science of the 1990s. Heyes provides compelling demonstrations of why imitation, mindreading, and language should each be seen not as innately-given cognitive instincts but as learned cognitive gadgets. In general, calling these neural mechanisms "cognitive gadgets" will be a catchy and helpful remedy for cognitive developmentalists who have been tempted to accept the notion of "cognitive instincts." But others may want a bit more detail regarding how these gadgets are actually constructed. For example, many non-nativist cognitive developmentalists will recognize cognitive gadgets as resulting from something like the learning-

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based *modularization* process described by Karmiloff-Smith (1995). Such processes are likely to have substantial innate *architectural constraints* based on gross neuroanatomy, but fewer *representational constraints*, because representations are based on more plastic fine-grain neuronal connectivity (Elman et al. 1996). There is already a large literature on how individuals' environments, including the social and cultural environments, shape fundamental aspects of their cognitive machinery (e.g., Karmiloff-Smith 1995; Nisbett et al. 2001; Nisbett & Miyamoto 2005; Henrich et al. 2010), and so we hope the additional evidence Heyes provides signals the end of overly simplistic nativist approaches to cognitive development. Beyond this statement, however, Heyes provides somewhat scant details regarding how gadgetization occurs. One of the few detailed examples given is the rather outdated dual-route model of literacy. Readers interested in a model that actually learns the way children do might be better served by Seidenberg's (2017) neural networks.

Savvy readers will also want to know more about how cultural evolution shapes the social learning environment that imposes this gadgetization. The most interesting part of Heyes's argument, in our view, is that the social environments that facilitate the development of culturally important cognitive mechanisms also evolve. This is an important point that has, to date, received too little attention. However, Heyes's presentation of how the relevant evolutionary dynamics occur is somewhat thin, and glosses over both the staggering complexity of those dynamics and the considerable progress that has already been made in describing that complexity.

Heyes characterizes members of "the California school" as being vague and inconsistent in their descriptions of evolutionary dynamics. Let us first note that "the California school" is an unfortunate term for many reasons, not least because it enables the author to ascribe to a collective a set of viewpoints without naming any individual sources, which would require attribution and subsequently allow scrutiny of those claims. Many of those associated with the referenced "school" have gone to great lengths to individuate their own research programs and clarify exactly the sorts of transmission, inheritance, and population-level dynamics they believe to have occurred in human cultural evolution, including using computational models, archaeology, cross-cultural fieldwork, and laboratory experiments.

In contrast, the evolutionary dynamics Heyes proposes are themselves vague. Let us consider her discussion of cultural group selection, which draws little from more established discussions (e.g., Boyd & Richerson 2002; Wilson 2002; Henrich 2004; Smaldino 2014; Zefferman & Mathew 2015; Richerson et al. 2016). The key point about multilevel selection or group selection is that selection on a social trait can strongly depend on the social environment, and so the contributions of each level of selection must be taken into account to analyze the overall population dynamics (Okasha, 2009). Altruists can be exploited by free riders within their group (individual-level selection against altruism) but still increase the *overall* fitness of their group relative to other groups (group-level selection for altruism). Additionally, prosocial norms often require coordination among social actors to provide marginal benefits, and therefore face difficulties in propagating in new communities (Boyd & Richerson 2002; Bicchieri 2006; Richerson et al. 2016). Understanding how such social traits spread is a key research area throughout the social sciences, encompassing not only the selection-based work in cultural evolution but also the epidemiology of beliefs pervasive in other areas of the social sciences (e.g., Sperber 1996;

Centola 2018). Heyes's evolutionary model (pp. 199-201) pays lip service to group selection, but closer inspection shows that her model is completely unaffected by group structure. In her model, trait M' always has higher fitness than trait M, so that it will spread regardless of group structure. There is no selection at the group level that is any different from selection at the individual level. This is a mistake, of course. The traits Heyes is talking about *are* social and will likely have different fitness gradients at different levels of selection, it's just that there is no mention of what the different gradients might look like. Heyes does briefly mention the potential importance of social complexity, but hardly enough. The consideration of emergent social structures that are important in cultural evolution is explored at length in Smaldino (2014). There is still a lot of important work to be done on understanding these evolutionary dynamics, and we agree with Heyes that the inheritance mechanisms for social structures is an important target for future research.

What makes understanding the cultural evolution of social organization so challenging? We suspect that the missing piece from Heyes's discussion is the complex feedback between extant traits and selection pressures and principles of organization (cf. Thompson 1942; Kauffman 1993) that shape those traits. In terms of the cognitive gadgets discussed in Heyes's book, one of the clearest perspectives on this front has been presented by Kirby, Smith, and colleagues (Smith & Kirby 2008; Kirby 2017). They have proposed that once humans had genetically evolved sufficient capacities for sociality, imitation, and cooperation, cultural evolution was sufficient to shape early communication systems toward easier understanding, production, and flexibility. Most importantly, they have provided dynamic models of how such a process might occur. Tomasello and colleagues have suggested more generally that social cooperation was a likely driver of the emergence of many uniquely human cognitive features (Moll & Tomasello 2007; Tomasello et al. 2012; Tomasello & Gonzalez-Cabrera 2017), which is consistent with but not a direct consequence of Heyes's central arguments.

In general, the processes of feedback across multiple organizational and temporal scales needed to explain the evolution of complex systems (Wimsatt 1972; Caporael 2003; Caporael et al. 2013; Smaldino 2014) are missing from Heyes's story, though their importance is hinted at in her final chapter. Implicit in this discussion of feedback is that, at some point in our evolutionary past, humans lived in social environments that were not well adapted to facilitate the development of many cognitive gadgets in the forms we now know (relatedly, it is likely that other gadgets, adaptive in past environments, have since been lost). Over time, humans constructed environments which promoted the development of new cognitive gadgets, which in turn facilitated the development of new environments, and on and on. Coevolutionary dynamics like this have, in fact, been increasingly studied under the banner of *cultural niche construction* (Kendal 2012; Laland & O'Brien 2012). This body of work explicitly targets the evolutionary feedback processes by which humans modify their environments (e.g., by producing new social institutions like writing), which in turn creates new selection pressures (e.g., by encouraging literacy), which in turn creates new opportunities for modifying the social environment (e.g., by producing new divisions of labor in which some individuals are express stewards of written knowledge), and so on.

All this creates problems for Heyes's central metaphor of grist and mills. There is a reason that the social skills essential to human cultural learning are reasonably well described as being

handled by cognitive "gadgets," in the sense that the word usually refers to cobbled-together thingamajigs. The reason is that the environments that led to the evolution of those skills were socially-constructed ones—a set of social niches constructed by the same species that was itself developing those skills. These gadgets were pieced together over time by a nonlinear unguided process, and therefore they are not pristine engineered devices. The grist was not already there to cause the formation of the mill, nor was the mill already there to cause the formation of the grist. As Heyes herself notes on p. 203, "the inheritance mechanisms for mills overlap with the inheritance mechanisms for grist." Thus, the social environments influencing development (e.g., the grist) co-evolved with the cognitive gadgets (e.g., the mills), bringing each other into being in a fashion not unlike autocatalysis (where two chemical reagents cause each other to come into prominence). To understand something like autocatalysis, one needs some facility with the dynamics of complex systems. Treating cultural evolution and cognitive development as though they are linear feed-forward processes that straightforwardly turn selection pressures into human traits just will not cut it. For example, the social mechanisms of language use and the neural mechanisms of language processing may not be well treated as "a grist" and "a mill," respectively, precisely because they overlap so much with one another (e.g., Clark 2008; Kirby, Cornish, & Smith 2008; Spivey & Richardson 2009).

Real mills are traditionally made of wood and stone, or whatever modern materials are currently in fashion. In our unpacking of Heyes's analogy, the mill is formed by the grist, which it then processes in such a way that changes the construction of subsequent mills. If grist can change the way the mill works, and vice versa, then perhaps grist-and-mill is not the right metaphor for understanding the cultural evolution of thinking (most mills don't reshape themselves as a result of changes in the grist that they are milling). If a metaphor is needed, a more apt one might be rivers and the water that runs through them. A riverbed channels the water that runs through a geographical area, but it can also get reshaped by that water. And the quality and flows of that water can change over time. If one embraces a river metaphor to illuminate this mutual relationship between cultural evolution and cognitive gadgets, it is easier to see how culture and brain can indeed shape one another. It also becomes clearer that culture and brain are not two separate factors that additively combine to generate mind. They are sufficiently interdependent that they might be best treated as one complex system, a distributed cognition composed of information that is transmitted via both neural fibers and social fibers.

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