



Argumentation Evolved: But How? Coevolution of Coordinated Group Behavior and Reasoning

Fabian Seitz¹

Published online: 22 January 2020
© The Author(s) 2020

Abstract

Rational agency is of central interest to philosophy, with evolutionary accounts of the cognitive underpinnings of rational agency being much debated. Yet one building block—our ability to argue—is less studied, except Mercier and Sperber’s argumentative theory (Mercier and Sperber in *Behav Brain Sci* 34(02):57–74, <https://doi.org/10.1017/s0140525x10000968>, 2011, in *The enigma of reason*. Harvard University Press, Cambridge, 2017). I discuss their account and argue that it faces a lacuna: It cannot explain the origin of argumentation as a series of small steps that reveal how hominins with baseline abilities of the trait in question could turn into full-blown owners of it. This paper then provides a first sketch of the desired evolutionary trajectory. I argue that reasoning coevolves with the ability to coordinate behavior. After that, I establish a model based on niche construction theory. This model yields a story with following claims. First, argumentation came into being during the Oldowan period as a tool for justifying information ‘out of sight’. Second, argumentation enabled hominins to solve collective action problems with collaborators out of sight, which stabilized argumentative practices eventually. Archeological findings are discussed to substantiate both claims. I conclude with outlining changes resultant from my model for the concept of rational agency.

Keywords Cognitive evolution · Rational agency · Argumentative theory of reasoning · Niche construction · Cognitive archeology

✉ Fabian Seitz
F.Seitz@em.uni-frankfurt.de

¹ Institut für Philosophie, Johann Wolfgang Goethe-Universität, Norbert-Wollheim-Platz 1, Room: 2.418, 60629 Frankfurt am Main, Germany

1 Do We Need An Evolutionary Account of Argumentation?

Humans have conquered almost any place in the world, mostly unparalleled by any other species. Why and how? One part of an answer is their ability to behave rationally.¹ Partly due to their rational agency, humans create strategies, theories, and artifacts to cope with almost any environment imaginable like no other. Argumentation is an essential aspect of this rational life.² Humans aren't solitary animals—to the contrary, we do much in cooperative fashion. In line with this, we often argue about what to do, how to achieve means or which information to rely on. Being open to arguments of others is also part of rational agency. Hence a minor part of our answer should explore what role argumentation plays in our conception of rational agency.

Another part of an answer comes from an evolutionary perspective. If rational agency is an evolutionary trait, we might be able to understand rationality only relative to the evolutionary history of all mechanisms involved (Sterelny and Jeffares 2010). Yet while there is a vast literature on cognitive evolution, and more than a few ideas on the evolution of rational agency and reasoning,³ the evolution of the cognitive underpinnings of argumentation is seldom considered (with one exception—see below). Thus, I aim to advance an evolutionary explanation of this part of rational agency.

We reach this end in three steps. First, I introduce and discuss the evolutionary account of argumentation most prevalent these days: Mercier and Sperber's argumentative theory of reasoning (2011, 2017). Although on the right track, I argue that their evolutionary account is too coarse-grained. It cannot, in principle, offer as much detail as would be desirable for an explanation of the origins of argumentation.⁴ Second, I sketch a new niche constructionist's variation on hominin cognitive evolution to fill this lacuna. Third, this variation is substantiated by empirical evidence on hominin evolution. I conclude with outlining resultant changes for our concept of rationality. The evolutionary perspective on argumentation developed here hints at a pluralistic and pragmatic conception. Before I begin, let me state a caveat: after the Sect. 2, the remainder of this paper will be a sketch of a much bigger project to come. As such, some of the linkages in the argument will remain fragmentary as well as many details and completions will be left open for discussion. In line with this, my aim in this paper is only to give a first glimpse of this project and to provide a 'prove of concept' for it.

¹ I have 'instrumental' rationality in mind here, the ability to find appropriate means to one's ends—for a discussion see (Over 2004).

² I follow O'Madagain and Tomasello (2019) here.

³ For instance, see Sober (1981), Cooper (2001) for rationality; and Cummins (2003), Stenning and van Lambalgen (2008) for reasoning.

⁴ Two more proposals have been made recently, namely Norman (2016) and Santibáñez Yáñez (2015). However, Norman (2016) is a variant of Mercier and Sperber's account, so my objection will apply to him as well; as does Santibáñez Yáñez (2015), which aligns with 'classical' adaptionism (see Fn 11 as well as my discussion in Seitz (2020); see also Richardson (2008)).

2 Precursors

According to Hugo Mercier and Dan Sperber (henceforth M&S), the primary function of reasoning is a social affair: for making and evaluating arguments. To put forward arguments is to present the reasons for one's belief or decision. Evaluating arguments is to check for oneself the value of other fellow's reasons. Do they support their proclaimed beliefs and purposed behaviors? The term 'function' here is part of an evolutionary hypothesis. For human animals, producing and evaluating arguments have proven adaptive in their past.

Adaptive to what? Already early hominin life relied on both cooperating and communicating. But depending on cooperation and communication might challenge social cohesion. Some might try to free-ride; others might try to deceive. Consider conversations. Mercier assumes: "Individuals who send information often have an incentive to cheat" (2013: 3). Thus, "mechanisms of epistemic vigilance have evolved that gauge the trustworthiness of informants" (*ibid.*). In general, M&S detect the crucial issue of trust in cooperative situations—hence a strong pressure to establish the bonds required for such activities.

According to M&S' account, arguing is an adaptation to this selective pressure. Individuals can generate trust by presenting themselves trust-worthy to others. And they can gain trust for themselves by reviewing information from others. They do produce reasons for others to display their reliability as partners. Others do check these reasons as they display. Reasoning, defined as a device for providing and evaluating reasons, is a mechanism to establish these practices.

M&S' account resonates with the standard approach of Evolutionary Psychology. Here is how Cecilia Heyes (2012) abstracts the core of this approach:

It suggests that the human mind consists of a large collection of computationally distinct 'modules'. Each of these modules is a way of thinking that was shaped by natural selection to solve a particular type of problem faced by our Stone Age ancestors. (2092)

This is also the blueprint for M&S' account of reasoning. 'Modules', as used by them, are not specific 'places' in the brain, but abstract theoretical entities (M&S 2017, ch. 4). Yet they show the following general features. They are 'units', processing only information of a particular kind, and work by inferences with specific rules. Both rules and type of information are adaptations to the task they have been selected for. The need of this task, in turn, is selected because of a particular situation. According to M&S, reasoning is such a module, too. The specific task is to argue to gain trust; for the specific situation—the problem to be solved—is one of mistrust. For this, reasoning is processing a particular kind of information: representations of reasons.

They need another premise. Once a critical situation selected for a cognitive module in the past, it was inherited unaltered up to us. Otherwise, we couldn't detect mal-adaptations today. If environments change while cognitive abilities don't, the latter maybe no longer fit current tasks. For this reason, M&S argue,

reasoning is mal-functioning in individual reasoning tasks, but not in group tasks (M&S 2017, ch. 11). The latter is crucial to justify their account.

To specify this, let me sketch Mercier's (2013) exposition on what M&S understand by a sound evolutionary explanation. First, one has to define "reasoning as a specific cognitive mechanism" (2013: 489). Second, one has to suggest an evolutionary "rationale". This is a scenario in which reasoning—as defined in the first step—would be adaptive. Third, "derive from this rationale the existence of specific traits of reasoning" (ibid.). This allows making verifiable empirical predictions. And finally: "reviewing the empirical literature to gauge the validity of these predictions" (ibid.). This yields the following explanation. Reasoning is to argue, and situations that require gaining trust selects for arguing. If true, subjects should perform better in group situations than in individual test trials. For in the former, reasoning is working following its original purpose; in the latter, it malfunctions. And indeed, as M&S have demonstrated, a lot of data fits their prediction (see M&S 2017, part IV for an overview).⁵

I consider the argumentative theory to be on the right track. Yet its evolutionary part might not be the strongest.⁶ I agree that the ability to argue was the solution to a problem our ancestors had to solve (although I do not think that this problem was due to mistrust).⁷ Ever since we turned into cooperative foragers, in need of coordinated group behavior (Tomasello 2014), we had to argue. But argumentation is a composite of coevolved traits. It consists of an elementary ability to reason (or to make inferences),⁸ communicative skills and the ability to follow norms.

If argumentation is such a composite, however, a problem for M&S arises. Evolution doesn't select for complex traits in just one step. To illustrate this point, consider the (manifold) evolution of eyes in the animal kingdom.⁹ A compound lensed eye enables high-resolution-vision. We know what these eyes are good for. Nilsson, for instance, enumerates "detection, pursuit, and communication with other animals" (2013: 6). We hence can make reasonable guesses what their evolutionary benefit was and might find ways to test them. However, eyeless animals did not turn into animals capable of high-resolution vision overnight. In a nutshell, eyes capable of high-resolution vision evolved from eyes capable of low-resolution vision, which in turn evolved from pigment cells capable of directional photoreception, the latter descending from cells only "monitoring the ambient light intensity" (ibid., i.e., non-directional photoreception). Each of the traits just named is a step in the trajectory towards complex eyes. And each of these steps had to be selected for in its own

⁵ Although for some experiments there exist alternative interpretations (e.g. Stenning and van Lambalgen 2008; see also Darmstadter 2013).

⁶ Note that M&S repeatedly justify their account as superior to others due to its evolutionary considerations (Mercier 2013; M&S 2011, 2017).

⁷ See Sect. 4.2.

⁸ M&S demarcate reasoning from inference (2017: 52–54). Inferences are widespread among animal minds, where reasoning proper is reserved to using reasons in one's inferences. I sidestep that issue here, using '(proto-)reasoning' as a term for making inferences till argumentation comes into play.

⁹ I follow Nilsson (2013) here.

right. For only if such a step persists within a population, it could function hereafter—given the right circumstances—as a platform for the next step.

So, if we want to survey the genesis of a trait in detail, from previous stages to the final trait in question, we need to account for a series of small steps (Calcott 2008; Sterelny 2017). We have to reveal how animals with baseline capacities of the trait in question could turn into full-blown owners of it. To reach this, we need to show how every precursor since this baseline could have evolved and transformed—until it transforms into its (preliminary) final stage with time. Plausible starting points and intermediate stages must meet likely occurred selection pressures. My suggestion is that something similar should be offered for argumentation.

Of course, the evolution of the vertebrate eye covers a time span of 600 million years (Lamb et al. 2007). Argumentation evolved much quicker. It is safe to assume that the last common ancestor, 6 million years ago (henceforth MYA), was not arguing. If we place the origin of arguing within early Pleistocene, the span of time up to the first arguers amounts to 3–5 million years. And still, it is unlikely that the evolution of all parts of arguing were without precursors over so many generations. If so, these proto-parts had to be adaptive on their own. Hence, we should target an explanation that marks the single steps of this trajectory.

But M&S can only offer explanations *as if* a trait evolved in one step. They do not have to assume that a trait indeed evolved just in one step, but they have no alternative than to depict the phenomenon in such a way. This is due to their theoretical framework of evolutionary explanations. They have to accept that a trait occurred only to a specific problem of a specific situation. Based on this, M&S cannot hypothesize about plausible candidates of previous stages. They have no means to reasonably define any function of a trait's predecessor. For they cannot vindicate hypothesized candidates by empirical means. The empirical testability of their evolutionary account hinges on experiments. But, if their framework is right, their participants only have the 'latest' version of a trait's 'final' stage. Thus, there is no way to test any previous stages with these subjects.

M&S thus cannot explain in detail what gave rise to this socio-cognitive hybrid, be it realized as a module or otherwise. Their account is too coarse-grained to account for a series of small transformations—from (proto-)reasoning towards argumentation as a social practice. Hence, granted we want to yield such an explanation, we need a new account on the origins of argumentative practices among hominins.¹⁰

Before I outline this alternative, note that their account is coarse-grained in another sense, too. It has no means to reasonably pick out narrowly enough *which* scenario selected for argumentation, given a base of plausible candidate scenarios.¹¹

¹⁰ Norman (2016: 691f.) also observes that M&S' theory cannot be about origins. Yet he forgoes to develop his observation into an objection against M&S' evolutionary method, presenting an alternative candidate for the function of reasoning instead. (To wit, to 'rewrite' other people's intentions). Hence, his account faces the same challenge as M&S' account does, although it seems he follows the idea that a full explanation of argumentative practice requires positing precursors (ibid.).

¹¹ Santibáñez Yáñez (2015) faces a similar problem: his proposal discusses some candidate scenarios why argumentation *could* be beneficial, yet without empirical background this is not enough to establish an evolutionary rationale (Seitz 2020). To consider which candidate scenarios are *actually* plausible, whether there were better pay-offs available or from which 'platform' a trait could have evolved

Their account motivates that (proto-)reasoning became adapted to argumentation. And, true, argumentation *would* be a solution to mistrust. M&S also provide good reasons to think that argumentation once became a solution for a problem in hominin history. However, the latter is not sufficient for the claim that mistrust *was* this problem. Any plausible scenario that requires argumentation must be gauged valid by the way M&S interpret the empirical literature. The characteristics they deduce to test their hypothesis are about group versus solitary reasoning, but not about reasoning in the face of trust versus mistrust. Hence, M&S can only assume that issues of trust could have been the selective regime, but we have no need to assume that it had to be so.¹² Other scenarios are plausible, too.

One more point. I am skeptical about the neuronal stability assumed by Evolutionary Psychology and, by implication, by M&S' account, too.¹³ This assumption does not match up with the high neuronal plasticity of human brains during both onto- and phylogeny, as new research indicates (Malafouris 2013; Anderson 2014; Overmann 2017). I take this as motivation to look for alternatives. One assumption is that cognitive abilities don't come into being by selection acting on existing variants, but arose out of interaction with the environment (Jeffares 2013). Another assumption is that cognitive abilities are to some extent self-made, where virtually all these models incorporate *niche construction theory* (Day et al. 2003). These elements combined can yield a new account on hominin cognitive evolution. In the next section, I present my version of such a composite to fill the lacuna of a missing lineage explanation.

3 Selecting Cognitive Skills

3.1 Argumentation and Reasoning (A Short Prelude)

Before I start, let me clarify the following.¹⁴ Arguing is a socio-linguistic practice and reasoning an individual cognitive skill—it is important to keep these abilities apart. True, I'm going to argue that reasoning (plus communication) enabled arguing, and the latter altered reasoning afterward. Nevertheless, reasoning and arguing should not be conflated with each other. Furthermore, I'm going to argue that argumentation evolved for justifying information 'out of sight'—this is, according to my

Footnote 11 (continued)

requires information about particular circumstances at a given time. And one needs empirical evidence to describe these circumstances.

¹² Frankly, I doubt that mistrust was problematic among our ancestors at this stage of hominin history. Indeed, I guess something is circular here. *Granted* reasoning as argumentation shall enable cooperation. If so, how is following norms of arguing established in the first place? For the latter requires cooperation. I have to postpone this critique for a later occasion.

¹³ Although M&S claim not to identify modules with specific brain structures, they have to assume stable neuronal structures to justify their premise that the reasoning module has been inherited unaltered up to us.

¹⁴ Thanks to an anonymous reviewer for pointing this out.

proposal, its evolutionary function. However, albeit I believe that the subject of this study is indeed the precursor of what we today mean by argumentation (and which henceforth is the subject area of argumentation theories), to build this link neither implies that they must be exactly alike; nor that any proper definition of *our* practice of arguing has to apply to this early precursor, too. Again, it is important to keep such things apart. With these preliminaries at hand, let's start.

3.2 Needs

To begin with, I assume the following as a reasonable scheme. An animal has a need, crucial for survival, hence the goal to meet this need. Reaching that goal involves producing a new state of the world. It does so by changing the arrangement of things (or some things themselves) within its reach. Thus, having needs foster the need to manipulate things. Furthermore, manipulating things attaches to needs not only in this straightforward way. Things can even create new needs after they have become part of the animal's inventory. 'Basic needs' then unfold into branching out sub-needs. All of this sets the stage for the dynamics of cognition.

To explain what an animal's mind is for in this setting, I follow Godfrey-Smith (1996). His basic idea: "the immediate role of cognition is to control behavior" (Godfrey-Smith 2002: 5f.). It is a means to produce behavioral flexibility, in order "to deal with environmental complexity" (Godfrey-Smith 2002: 5f.; see also 1996: 13). Depending on its needs and habitat, an animal must be capable of a certain level of behavioral flexibility. This forms the complexity of a mind. For animals have to carry out *specific* behaviors. This requires whatever *particular* cognitive abilities the animal needs to conduct *this* behavior. All this in response to a given environment it has to cope with.

How does behavior then form the cognitive skill of reasoning? First, I propose the following: if cognition is all about controlling behavior, then the activity of (proto-) reasoning is there to control behavior, too.¹⁵ Second, behaviors unfold in line with a certain complexity. A behavior ranges from a subject's awareness of a need up to a goal state that satisfies this need; thereby the subject has to tackle obstacles on the way. The behavioral sequence consists of different steps here, which must be executed in the right order. Therefore, there is a need for coordination: to coordinate the different subparts of behavior in a way as to achieve the primary goal. Otherwise, successful behavior wouldn't be possible. Now, this need to properly coordinate the parts of a sequence fosters the need to integrate all information required, as it were, from a 'vantage point'. One must always have the ability to work any information necessary for a task. It grounds the need to integrate all the information required: information across many domains, depending on the single parts and sub-tasks involved.

In other words: both kind and amount of information to be combined are set by this requirement for coordination. This requirement, in turn, is relative to the

¹⁵ As stated here, it is only an assumption to get started. It will have to vindicate itself by enabling a reasonable evolutionary trajectory in the remainder of this paper.

behavior that has to be coordinated. Eventually cognitive skills are selected for combining all this in such a way as to put a behavior into practice with chances of success. Following my proposal, reasoning prepares and accompanies this practice. If so, the function of (proto-)reasoning would be to work up information in such a way that it enables the right orchestration of behaviors. Reasoning, then, is this activity of coordinating behavioral parts and information: to construct behavioral sequences in mind and to incorporate information before and during execution.

What finally determines the cognitive work, however, are the *things* used to meet one's needs. For they determine the required behavior sequences. I elaborate how in the next section.

3.3 The Cognitive Burden of Things

There is yet another aspect of Godfrey-Smith's framework. Achieving goals depends on how an animal has to interact with its environments. Thus, there is a relation between the kind of environment to the particular behavior. Complex environments tend to demand complex behaviors. The latter tend to demand complex cognitive skills. Here Godfrey-Smith's notion of 'environmental complexity' enters. There is more than one way to spell out this notion (Godfrey-Smith 2017), yet to characterize the complexities involved here I am going to rely on Hodder's (2012) idea of *entanglement*. (Note that nothing in the overall-argument depends on this choice: the account presented below would also work with other ways to characterize environmental complexities.)

Entanglement is a set of relationships. Agents relate to things, things to agents, and even things itself often relate to each other. Entanglements create specific dependencies thereby. First, agents have to rely on things to adapt to their environment. These things enable them to meet their needs. Second, they have to care for these items. For artifacts "cannot reproduce on their own" (2014: 30). Hence one has "to look after them, repair them, replace them, manage them" (2014: 30). Control of these artifacts and their components is crucial (cf. 2014: 33). This implies an important aspect. Depending on things to meet one's needs made one even more dependent. It demands to cope with everything necessary to get these things in the first place. Here the notion of entanglement can be used as a *tool* for fixing analytical units. Agents use artifacts, but one should not regard artifacts as fixed entities. Instead, as a set of dependencies, which have to be considered from an agent's perspective.

This makes the notion of entanglement as used here agent-relative. To allege an example, many people today use electronic devices. There are many entanglements attached to their production. For instance, mining of rare earth, global trade, global division of labor, and so on. But despite this, the entanglements the average user has to cope with are different. An entanglement they have to consider might be the ability to use specific symbolic systems. This sounds trivial, but this agent-relative notion of thing-skill-entanglement makes a difference in explaining cognitive evolution.

For artifacts foster human thought in many ways.¹⁶ Creating and sustaining them is one possibility. It requires cognitive resources of its own. Starting to use artifacts create subordinated needs. One has to transform raw materials. Forming the material into its shape is required. Knowing where to get raw material from, and include this into one's daily routines, is required, too. One also needs to know how to maintain an artifact.

Artifacts thus demand certain cognitive abilities due to these connections. An artifact's entanglements demand a particular manipulation of the environment to handle them. It requires skills in decision making and resource management. Entanglements thus imply cognitive activities such as planning. In the abstract: An agent has to manipulate things for meeting one's primary needs. The entanglements of these things create the complexity an agent has to cope with. The latter characterizes cognitive demand then. Thus, the entanglements of things drive the complexity of cognition.

This order can be reversed for analysis. To some extent, one can read off from an artifact the entanglements an agent (from his standpoint) has to handle. For this, knowledge of the particular ecology must be integrated, too. Then, one can also read off the required handling of knowledge for control and resource management. The latter then allows for reasoned speculation about the cognitive abilities used. Thus, one can analyze from an artifact which knowledge had to be handled and which general rules of thought had to be followed to get this very artifact.¹⁷

This also holds true for our ancestors and us. During hominin history, we happened to become depended on particular things to fulfill our needs. Our entanglements specified the minimal requirements of cognitive abilities to handle them. All things we once were entangled with thus drove our cognitive evolution. I turn now to this step in the overall-loop.

3.4 Niche Construction: First Steps

Niche construction is a systematic change, which organisms bring about within their environments (Day et al. 2003). These changes can alter selective pressures for themselves and their offspring. Modified niches change the selective regimes for the next generation. This can become an important factor in the evolutionary dynamics of a species. A prime example is a selection for lactose tolerance in those *Homo Sapiens* groups (and only those), which engaged in the practice of dairying (Boivin 2008: 200f.). For my purpose, two aspects stand out. First, niche construction plays a role within the cognitive capacities of its inhabitants. For niche construction and cognitive adaptations interact. Second, niche construction can result in evolutionary feedback. For "organisms drive environmental change and organism-modified environments subsequently select organisms" (Laland and Brown 2006: 96). The latter again alter their environments for their descendants.

¹⁶ There are more accounts worth mentioning, of course, but for reasons of space, I concentrate on my proposal.

¹⁷ This is akin to the chaîne opératoire-approach in archeology (Leroi-Gourhan 1965).

Niche construction can alter cognitive development directly. Take, for example, the *transformation thesis* of Sutton (2010) and Menary (2007; 2015: 8f.). A transformation of cognitive abilities can occur due to change in the cultural niches. Menary's Cognitive Integration theory, for instance, maintains, "along with niche constructionists (Laland et al. 2000), ... a phylogeny of hominid cognition in terms [of] their active embodiment in a socially constructed niche" (2015: 3). Constructing new niches hence leads to new cognitive abilities.¹⁸ This change is based on the idea that the mind extends beyond the brain. Hominin minds couple with all kinds of artifacts to perform cognitive tasks. If the artifacts change, so does cognition. But Menary (and Sutton) employ here a specific class of things: cognitive artifacts (Hutchins 1999). Examples of such artifacts are writing and number systems. These are instances of a more general phenomenon: humans invent both material artifacts and practices, which in turn alter their cognitive abilities.¹⁹

One can give this a more historical bend. Osvath and Gärdenfors (2004) (henceforth O&G) also employ niche construction. But they analyze the cognitive evolution of early hominins. Furthermore, unlike extended mind theorists, they concentrate on non-cognitive artifacts. These can have transformative effects on cognitive evolution, too. For, according to O&G, a changing hominin niche 2.5 MYA caused coevolution of transport and planning. Transportation of raw materials and tools expanded at that time. Hence behavior sequences stretched more and more. Finally, according to O&G, anticipatory planning became mandatory. For hominins planned these behavior sequences. Yet to handle these ever longer transports, they had to plan in anticipatory mode at a certain level.

I discuss the empirical details involved here in a moment. But I focus on another aspect than the mere length of behavior sequences. Recall that cognition can change through time due to a change of material things surrounding it. For changing artifacts within a niche is also changing their entanglements. For the agents involved, this changes which items of an environment they have to track and cope with. Thus, it selects for cognitive skills to handle this. This idea will now be combined with niche construction.

3.5 The Model

The complexity of a niche selects for the behaviors required to cope with this very environment. That way, it selects for the kind of reasoning abilities needed to coordinate (some of) these behaviors. However, this dependence is no one-way affair. Transforming an environment is a behavior itself, and so the ability to coordinate a behavior is not only something that gets adapted to external pressures. It also creates new pressures since behavioral coordination can become a powerful 'tool' for niche

¹⁸ Therefore, "we should be searching for archaic precursors to modern cognitive capacities" (Menary 2015: 6).

¹⁹ This is, of course, only a highly abbreviated sketch of 4E cognition. Due to lack of space, I cannot elaborate on it any further (for a recent overview see Gallagher 2017, ch. 2).

construction. It enables agents to create new behaviors and hence to modify their niches on their own.

The possible complexity of such coordinated behaviors might increase with ongoing generations. These behaviors then might enable a more complex environment. Afterward, it will create new selective pressures of its own. The situation will select for being able to cope with the imposed complexity. It selects for reasoning skills able to do this. Descendants then might be able to construct cognitively more complex chains of action than their ancestors did. By doing so, they might be able to handle even more complex environments. Thus, they will be able to create even more complex niches than his ancestors could ever have.

This applies to artifacts as well. Recall the notion of entanglement. The more entanglements can be managed and controlled the more complicated artifacts can be produced. Hence, niches can become more complex. There can be more entangled relations between different objects or different parts of objects to be assembled. This can also be a group activity. Single individuals of a community might be able to manage and control bigger entanglements. Due to this, they might create new, sophisticated artifacts. But these artifacts can be used by the whole community later on. The whole niche gets enriched with these things. Hence entanglements to be managed and controlled can scale up for their descendants. The cognitive burden to handle all this follows.

Putting all these considerations together yields the following feedback-model of hominin cognitive evolution. *First*, a niche of a certain complexity selects for the ability to manage and control the entanglements related to that niche. Thus, such a niche selects for reasoning abilities able to accommodate this. *Second*, given such new reasoning abilities developed, it allows for more complex behavior. Moreover, it lets them handle even more complex entanglements. This, in turn, can cause an organism's niche to change into a more complex one. *Finally*, the possibility of a loop arises. More complex niches select for the ability to handle these even more wide-ranging entanglements. So again, this newly created niche selects for reasoning abilities able to manage these even greater entanglements.

If an adaptive response is within the realms of possibility, that is. As I elaborate below, most often this is realized by combining already existing abilities in new ways. Or by creating—with already existing abilities alike—a new cognitive artifact, which in turn enables the adaptive response. Both ways explain without miracles how hominins could get from precursor to successor state, once the need to get one step further has been installed. For example, by external pressures like ecological or social change.

And again, such composite cognitive skills will allow an organism to create an even more complex niche. This, if possible, will select for even more sophisticated reasoning skills then again. Here the proposal what had happened at an abstract level (Fig. 1)..

This model provides a blueprint for yielding a plausible sketch of an evolutionary trajectory. Applied to the Oldowan niche, it explains change in the cognitive skills of these hominins—from individual (proto-)reasoning towards the ability to argue.

4 The Evolutionary Trajectory towards Argumentation

4.1 Australopithecines: The Baseline

Four MYA, the earth went through global cooling. This induced serious consequences for our ancestors. Homogenous woodland habitats became more heterogeneous, open savanna-like environments. With this change towards ecological variability, the genus *Australopithecus* arose 3.5 MYA. Their increase in brain and body size were modest compared to chimpanzees (McHenry 1992; Kappelman 1996). But their anatomy of locomotion was different. They were the first compelled to bipedal walking.

This morphological adaptation was accompanied by a shift in foraging. Apes prefer soft foods like fruits, with leaves and plants as a fallback option (Laden and Wrangham 2005). However, the thick enamel of australopithecine molars suggests that they consumed underground storage organs (USOs) like roots and tubers to satisfy their hunger (Ungar et al. 2006). New subsistence behaviors implied a new way of life: USOs must be found and dug out (Coolidge and Wynn 2009: 89), probably by using wooden tools (Wynn 2002: 393). The entanglements of these roots imposed selective pressure towards expanded foraging sequences. USOs are widely scattered over the landscape. So the need arose to extract buried food at a larger home range, inducing a new behavior: long distance transporting (Jeffares 2010: 164).

Here, too, behaviors have to be executed in the right order for changes of success. If such sequences are to some extent anticipated or planned, there likely is a kind of mental orchestration of single parts. This might not involve the ability to anticipate a complete 'mental template' of a behavior sequence. Yet already great apes conduct complex, hierarchically organized behavior, such as termite fishing, nut cracking and nettle stripping (Byrne 1997, 2000). Sometimes this involves assembling different parts of their tools. Nut-cracking requires hammer- and anvil-stone. Often Chimpanzees have to transport them to the place of use, although seldom more than a few hundred meters (Boesch and Boesch 1984; Boesch and Boesch-Acherman 2000). One can take this as a platform for Australopithecine's capabilities.

All in all, this formed australopithecine cognition. The size of home range influences resource management. The latter influences which planning abilities are required for managing them. They might have had the ability to remember the location of foods and raw materials. Furthermore, they used short, planned actions to extract the former. This suggests that they had the cognitive abilities to handle long behavior sequences to meet their needs. Thereby they had to integrate information on the go. Yet there was only a demand for slight anticipation in their doings.

And of course, Australopithecines communicated. No language has evolved yet. But let's take great apes as a baseline again. Then they would have employed learned signals to communicate. At least about their wants, and maybe about things present in the concrete here-and-now of their surroundings. Most likely, they used gestures (Sterelny 2012b). These abilities set the stage for the ongoing development of hominin cognition.

material increased significantly in the Oldowan. It starts with 2–3 km transports at 1.7–1.85 MYA, over 10–13 km transports at 1.8 MYA, up to distances about 15–20 km undertaken at Koobi Fora at 1.64 MYA (Bunn 1994; Hay 1976; Potts 1984; Ohel 1984).²¹

Furthermore, hominins had to search for cadavers, as animals did not always die at the same spot. Regarding accumulation, evidence from sites like FLK at Olduvai Gorge (Bunn et al. 1986) indicates that animals were not consumed at the place where they died. At FLK, many leg bones were found, but only a few parts of the axial skeleton like shoulder blades or pelvis bones. It seems that parts of animals killed by carnivores were transported to safer places near river sites. Only then was meat cut off and the bones smashed (Blumenschine et al. 1987).

Making Mode 1 tools demands no more cognitive abilities than extracting USOs (cf. Joulian 1996). Furthermore, scavenging in itself might not account for an “obvious leap in intellectual ability required” (Wynn 2002: 394). But this is only half-way right. Even if hominins needed no higher intelligence for the task, they required specific kinds of stone. Hence raw material acquisition changed. It forced them to a way of life of exploiting ever larger parts of the surrounding environment. Tool transport seemed to be a usual part of a stone knappers’ life in Oldowan. Taken together with the scavenging subsistence strategy, it implies increasing mobility.

Let’s sum up the state of play. A new niche fostered the need to rely on carcasses. This, in turn, implied the use of stone tools for this scavenging behavior. These tools have specific entanglements. Their raw materials are scattered around the landscape, often far away from the final place of use. An Australopithecine mind brings along the basic elements to handle this, but it has to adapt to extended foraging sequences. But the extended home range is not the only novelty. An important change in the social organization is implied as well. Stone tool production, scavenging, and transport of carcasses required a new level of coordination between single hominins. They started to turn into cooperative foragers. Hence, they were able to combine “reliance on extractive foraging ... with the capacity to cooperate and coordinate” (Sterelny 2012b: 2142; see also Sterelny 2012a).

Cooperative coordination of behaviors requires special skills to succeed. Most salient, this kind of life requires ‘informational cooperation’ (Sterelny 2012a: 76f.). No one can have all information required to execute the workings of a whole group; hence information must be merged from different sources, attained by different individuals (ibid.: 138f.). This, in turn, necessitates having a constant flow of information between single agents. The whole group must be cognitively equipped in a way to allow for information pooling. To wit, sharing and exchange of publicly announced information, and communication about the content of a statement (ibid.: 76). Individuals need to have access to this information. Otherwise, they would not

²¹ See also Marwick (2003), which links the archeological evidence of increasing raw-material transfer to the evolution of language. I side with Marwick’s account in general, but (have to) disagree with a detail: Based on my interpretation of early Pleistocene raw-material transfer, following Bickerton (2014) and Rouse (2015), I localize the ability to express displacement in the (perhaps late) Oldowan period, where Marwick sees no conclusive evidence for this (2003: 71). See also Fn 22.

be able to execute their part within the cooperative constellation. And “much of this information [is] not proximal; it [is] remote, ‘theoretical’ information” (Jeffares 2010: 167). Episodes of reasoning will have to be composed out of information from sources beyond one’s own encounters.

This is crucial. The entanglements of the Oldowan complex fostered a kind of information pooling of things ‘out of sight’. The groups now relied on information about where one individual had spotted a carcass. But it is information about a thing not immediately present to the group. This ‘out of sight’-information, in turn, had to foster new ways of verifying it. In other words: the new entanglements of stone tools and cadavers created new needs to which the Oldowan hominins had to adapt. This challenge had to be met in part with new cognitive abilities.²²

Because of this new kind of information pooling, we now have to reframe M&S’ initial cognitive challenge. I propose something similar to Sterelny (2012a: 129f.). What matters is not trust in our cooperative partners; it is how we might be sure that they don’t err in a bewildering world.

The required cognitive abilities to solve this problem have been there already. Hominins already had communicative skills, but now those had to be adopted to refer to things not immediately present. Therefore, new skills to communicate information emerged (which M&S have to presuppose for their account, too). Furthermore, the ability for individual (proto-)reasoning existed already. Australopithecines had used it to cope with the informational burdens of managing their home ranges and (likely) producing tools for extracting tubers.

Reasoning, combined with communicating, could meet this challenge. Being aware of the possibility of false beliefs, and hence that I could be mistaken but you could be right, is a prerequisite for the social practice of argumentation to emerge—a building block that could have been obtained already by the hominins of the (perhaps late) Oldowan due to their communicative skills. Furthermore, these skills, combined with reasoning, were already sufficient to avoid or correct concrete false beliefs in group planning.

First, if communication progressed into a proto-linguistic ability, able to refer to things out of sight, it could also turn into an auxiliary tool to avoid false beliefs. This must have been crucial for Oldowan hominins since being mistaken about a state of affairs when planning a course of action could be life-threatening for the whole group. Given the specific ‘out of sight’ scenarios they found themselves in, there was no easy way to prove whether a belief was false or not (‘Is the carcass this direction or over there?’). Yet any belief mistakenly accepted at the start of a planned group activity could potentially stay unrecognized as an erroneous one up until much later during the execution of this activity; potentially too late to correct this believe to avoid disaster.²³

However, as (O’Madagain and Tomasello 2019) have argued, given sufficiently linguistic skill, humans cannot only jointly attend to external objects like stones or

²² Bickerton (2014) and Rouse (2015) have argued that this scenario was the origin of human language, or, more precisely, of referential terms used in a proto-language. I assume this is on the right track, although I have no space here to discuss this hypothesis.

²³ Santibáñez Yáñez (2015), in my view, rightly observes that argumentation evolved to benefit whole groups, not single individuals.

trees: they can also jointly attend to publicly expressed contents of mental states of others. This, in turn, allows for the awareness of false beliefs. For they argue that ‘joint attention to mental contents’ fosters what they call “multiple attitudes”: the ability to recognize “that what I *believe*, you might *disbelieve*” (ibid.: 2). Hence, I realize that something I believe to be the case could also be not the case. The ability to refer to remote entities seems enough of a linguistic skill to evolve into something capable of this.

Second, communication involving displaced references might have selected for agents being capable of understanding signals not only as imperatives to do something or pointing out to immediate (i.e., perceptually visible) states of affairs. Instead, they might also have been able to signal whole sequences of events to others.²⁴ Sterelny argues that hominins acquired displaced reference via skills for tool production (Sterelny 2016a, b). With new technical skills emerging, hominins needed to be capable of sequencing their behavior in mind, without external stimuli triggering those sequences (2016b: 177). Furthermore, by acquiring those skills via social learning, these apprentices had to recognize demonstrations of a behavior as a ‘blueprint’ for one’s correct execution of this very behavior. (For instance, an instructor making a stone knapping movement without actually knapping the rock—to show his trainee how to apply correct angles, application of force and so on).

Following Sterelny, this was a platform to evolve into displaced reference. On the one hand, it fostered hominin cognition with stimulus-independent ‘inner templates’ of sequences. On the other, hominins were now able to communicate mimicked behaviors as signals of these very behaviors (for instance, emulating the practice of ochre grinding without ochre (ibid.)). If so, hominins could signal sequences of action to others—and the receivers could recognize such a signal as a reference for a series of behavioral events.

These abilities could solve the problem of justifying uncertain ‘out of sight’ information within a group. Hominins already understood displaced reference and could signal the structure of a behavior sequence to others. Getting from this to signaling a series of how events hang together is not an unbridgeable step. The latter, in turn, could be exploited to communicate one’s own episodes of reasoning to others to change their beliefs about a state of affairs. The details are speculative, but here is one possible way. Oldowan hominins could use their pre-existing abilities as follows. First, how to combine information to produce a behavior. And then, to communicate to others just that: How they would behave because of the way they would combine the information at their disposal. Other members of the group could then evaluate these signals on their own. Perhaps by matching signaled sequences with their own ‘inner templates’. In the long run, preferable reasoning communicated to others were filtered. Only successful reasoning could be selected. Successful means:

²⁴ The following is, again, of course only a sketch. Since Sterelny’s account is neither the only game in town nor undisputed, I will have to provide a complete discussion of it (including objections and diverging accounts) in the future.

it led to verifying information in a way that allowed for coordinated group behavior to be successful. In the long run, these selected episodes of reasoning might have turned into the first stock of ‘standardized’ signals for arguing.

Once established, argumentation is augmenting reasoning. Argumentation, like any skilled practice, is guided by norms, implicit via imitation learning or explicit via some teaching. There is a positive feedback loop here. Norms for arguing in public became ways to reason for the individual. 4E-cognition enters here. In particular, the idea that even cognitive skills like reasoning are shaped by social practices.²⁵ For social practices structure the learning environment, and—granted that hominin brains are highly plastic and adaptable—learning alters cognition in turn. After reasoning plus communication established the social practice of arguing, this practice transformed individual reasoning abilities then again.²⁶

If all these considerations are on the right track, this model explains the incremental transition from the Australopithecines to the (perhaps late) Oldowan cognitive niche. New entanglements led to the cognitive adaptation of handling bigger loads of information in reasoning. Furthermore, they led to a new kind of socio-cognitive practice: arguing. That is verifying information by signaling one’s episodes of reasoning—once used to coordinate single behavior—to others. These newly acquired abilities created new possibilities in niche construction. For example, exploiting increasingly larger home ranges and resources. In the long run, this fostered new artifacts and ways of life that all depended (and still depend) on these abilities. I end my exposition by arguing for the beginning of this stabilizing process.

5 Stabilization

The answer to new selection pressures—*Homo Erectus*—came around 1.9 MYA (Walker and Leakey 1993; cf. Wood 1992). Erectus was the first in our lineage with modern human anatomy (Plummer 2004), allowing for enduring bipedalism (Meldrum and Hilton 2004). The cultural change also accelerated. Their niche consisted of both inventions and extensions of previously existing behaviors. They manufactured more complex tools (Coolidge and Wynn 2009: 111), and subsistence changed. Due to larger brains and extended mobility, they demanded more energy, up to 80–85%, compared to the Australopithecines (Leonard and Robertson 1997). Likely, Erectines satisfied this need with higher meat-intake through more aggressive scavenging (Domínguez-Rodrigo et al. 2002).

Greater reliance on animal protein necessitated exploiting much larger territories²⁷ to support the group (Antón and Swisher 2004; cf. Antón et al. 2002), with long-ranging day trips in hot environments being a stable feature of their life

²⁵ To get illustrations of this idea, see for the case of mathematical reasoning, e.g. Menary (2015); for logical reasoning Dutilh Novaes (2012: Ch. 5); and for mind-reading skills Heyes (2018: Ch. 7).

²⁶ Indeed, O’Madagain and Tomasello (2019: sec. 4) also argue for the claim that exposure to arguments alters one’s reasoning abilities. Following this, O’Madagain (2019) argues that human reasoning is partially a cultural trait that has to be learned and can be altered during cultural transmissions.

²⁷ Following one estimate, home ranges became ten times larger (Coolidge and Wynn 2009: 117).

(Plummer 2004). But large home ranges make social lives complex as well. Likely aggressive scavenging had to be executed as a joint action to be energetically worthwhile.

Consequently, the Erectines' niche became cognitively challenging. For resource management and decision making changed along a bundle of lines. Larger home ranges imply more opportunities: hence there is a higher probability that increased behavioral flexibility is needed. Coordination became more demanding as well, for behavioral complexity increased: hominins now produce more complex tools and need to engage in more wide-ranging scavenging.

Furthermore, use of fire emerged. Archeological evidence about the controlled use of fire is scrappy, yet solid evidence for controlled fire-use so far dates back to 0.8 MYA, for example in Gesher Bent Ya'aqov (Goren-Inbar et al. 2004). Fire is a much more complex artifact than one might previously imagine. Consider its entanglements. Digging tools must be produced for the fire pit. Wood is cut down and collected, dry grass too. Cutting and collecting require tools of their own. Hence, use of fire implies planning on a different scale: timing becomes important, for fire is neither found continually in certain places nor something to leave unattended even for a short amount of time. Hand axes can be stored temporarily without giving them much further attention; one cannot do that with fire.

So probably Erectines had to cope with a huge number of situations in coordinated planned action. More to the point, as home range increases single individuals had to cope with their parts of coordinated group behavior much more on their own. If so, this created a collective action problem of a special kind. The problem of coordinating one's actions in the face of coordinated group behavior exacerbates when confronted with extended home ranges: spatial distance between single individuals will be too big to coordinate one's actions by signaling to each other; meanwhile, timing requires to execute specific behaviors in specific timeframes. Thus, some parts of the overall plan have to be executed in parallel by different agents at the same time. Fire seems to be an artifact priming such scenarios.

Consequently, making decisions on the fly is not just a problem of information, but one of how this information should be worked, too. For all reasoning in place is obliged to be 'compatible' amongst different agents. It must be guaranteed that information would be reworked nearly the same way by every agent. Otherwise, this could lead to unfitting results: the same information would lead to different outcomes in different agents. This sometimes happens. But it cannot be the general rule if any cooperative activity shall ever have any chance of success. Likewise, if agents have to change something on their part of the plan, they must be sure that it will still fit with the rest of the other parts. In principle, these cases are extensions of the need to coordinate: extended from the level of the subject towards the intersubjective level of the group. To establish this requirement a shared normative set of rules for reasoning is required: a standard—as the only obliged way—on how to work all information needed. Expanded cooperative activities thus select for an adherence to publicly shared norms for reasoning.

If the first part of my evolutionary trajectory is true, the norm-adherence established by the Oldowan niche solves this problem by allowing all members of the group to think within the same patterns. Because in the course of justifying, the practice of arguing with each other allowed to establish norms for reasoning for all members of a hominin group. The new argumentative norms got internalized and establish new reasoning abilities within the individual members of the group.²⁸

The consequence was, as it were, ‘synchronized’ thinking. This propelled coordinated cooperative behavior onto a new level. Now it was possible to complete overall-behaviors by completing single parts on one’s own. Even if no signaling to other members of the group to coordinate one’s action was possible.

No genetic mutation had to occur for this adaptation. To establish these norms already sufficed. An ability already there, as indicated by the archeological record of long-standing tool-making traditions. Hominins already knew how to pass norms for skills from one generation to another. Informational cooperation selected for the skill of arguing. This skill, in turn, allowed to solve collective action problems, where collaborators are out of sight of each other. Eventually, this skill enabled sophisticated artifacts like fire.

Once again, here is a positive feedback loop. Once established, the presence of such a thing, with all its entanglements to be coped with, reinforces the way how to handle these entanglements. To wit, the norms that allow reasoning in a way as required—that is, in a way as to produce the behavior needed.

6 Concluding Remarks

Argumentation is part of our rational life, and so argumentation is important for our concept of rational agency. An evolutionary perspective on argumentation would help to refine this notion, yet the account most prevalent these days—M&S’ argumentative theory—faces a lacuna. As I argued, it cannot explain the origin of argumentation as a series of small transformations: from hominins with baseline abilities of the trait in question to full-blown owners of it. I thus proposed an alternative; and this proposal may alter our conception of rationality, as I briefly outline here in conclusion.

First, this alternative model can plausibly suggest how argumentation occurred. The first problem, which gave rise to argumentation, was handling ‘out-of-sight’ information. The second challenge, which is solved by argumentation, is to handle decisions out of sight of your collaborators. This two-step procedure offers three explanations at once. Why argumentation had to evolve. How this happened. And why and how this social practice got stabilized in the long run, down to the present day.

²⁸ This is not a social affair only, though. The experience of individuals also forms the way they reason. So, it is neither ruled out that individuals can come up with new ways to reason on their own, nor that some basic ‘rules’ have been part of their reasoning abilities from the beginning—already formed by interacting with one’s environment alone. *Modus Ponens* and *Disjunctive Syllogism* cross one’s mind.

Second, the model has a further advantage. M&S seem to fear one consequence of their account: relativism. If reasoning is for arguing and arguing is for generating reasons “for social consumption” (2017: 123), by what are the rules of arguing established? How are, accordingly, the rules of reasoning (and rationality) established? On their account, one could initially assume that argumentative standards are just ‘social constructs’ of the group, and hence only justified relative to the—maybe irrational—culture of these constructionists. To avoid this consequence, M&S claim that there has to be something such as “objective rationality” to which underlying inferential procedures had already adapted prior to arguing (M&S 2017: 143f.). Unfortunately, M&S don’t elaborate what constitutes ‘objective rationality’ according to their view. Hence, they offer not much insight into the procedure that selects the concrete content of rationality: the rules by which we should reason.

My alternative account, on the contrary, reverses M&S order of arguing and rationality. This way it hints at an interplay between group activity and rationality that does not fade into unwarranted relativism. Rational agency in part consists of justifying one’s doings in retrospect. Or using the same rules with foresight: to figure out what to believe as well as to deliberate and reflect on what to do. Yet on the sketch presented here, justification consists of argumentative standards: since *Homo Erectus* at least, the argumentative practice sets the rules also for individual reasoning. This practice, in turn, unfolds due to groups coping with their physical and cultural surroundings.

Argumentation is for channeling information in cooperative activities in such a way as to establish successful interaction with their environments. When environments change, collective planning and other coordinated group activities might also have to change. Informational cooperation then alters, too. Consider different spatial and temporal scales, modified local knowledge, and coordinating new tasks following this more diverse information. Here hominins need new ways to account for previous unconnected bits of information, and for ways to justify or reject this information. This selects for argumentation rules that reflect these demands. And new norms of argumentation, once established by the group, get internalized by its members then again. From here on they are individual cognitive skills. Therefore, if surroundings change, so do any informational cooperation involved—and so do standards accordingly.

Ideally, at least. The account shares one important implication with Cecilia Heyes (2018) ‘Cognitive Gadget’ theory: if even basic cognitive skills depend on culture, any loss of culture means losing even those skills (Heyes 2018: 217f.). Dramatic changes in one’s niches might not only require new ways to cope with it but also lead to a “skeletal, traumatized population” (Heyes: *ibid.*). Then such a population might find no way to adapt its argumentative practice to this challenge.

Likewise, hinged to niches we constantly re-create, we are in a constant struggle to re-adapt. With niche construction accelerating in the more recent past of our lineage, this might turn out to become a challenge as well.

Regardless, rational standards are neither uniform nor steady on this picture. The ongoing development of ways to cope with one’s environments, and hence the need to find new ways to argue, fosters human rationality always anew. This yields a broadly pragmatic conception of reason (Johnson 2017). If true, an evolutionary

perspective on argumentation might adduce good reasons to a pluralistic conception of (human) rationality. Yet it would be a warning, too: we would be obligated continually to strive for new, ever-changing norms of rationality to get things right. To elaborate on these ideas is the next step in the development of the account presented here.

Acknowledgements Open Access funding provided by Projekt DEAL.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Anderson, Michael L. 2014. *After Phrenology*. Cambridge, MA: MIT Press.
- Antón, Susan C., William R. Leonard, and Marcia L. Robertson. 2002. An Ecomorphological Model of the Initial Hominid Dispersal From Africa. *Journal of Human Evolution* 43 (6): 773–785.
- Antón, Susan C., and Carl C. Swisher III. 2004. Early Dispersals of Homo From Africa. *Annual Review of Anthropology* 33: 271–296.
- Bickerton, Derek. 2014. *More Than Nature Needs*. Cambridge, MA: Harvard University Press.
- Blumenschine, Robert J., Henry T. Bunn, Valerius Geist, Fumiko Ikawa-Smith, Curtis W. Marean, Anthony G. Payne, John Tooby, and Nikolaas J. van der Merwe. 1987. Characteristics of an Early Hominid Scavenging Niche [and Comments and Reply]. *Current Anthropology* 28: 383–407.
- Boesch, Christophe, and Hedwige Boesch. 1984. Mental Map in Wild Chimpanzees: An Analysis of Hammer Transports for Nut Cracking. *Primates* 25 (2): 160–170.
- Boesch, C., and H. Boesch-Acherman. 2000. *The Chimpanzees of the Tai Forest*. Oxford: Oxford University Press.
- Boivin, Nicole. 2008. *Material Cultures, Material Minds*. Cambridge: Cambridge University Press.
- Bunn, Henry T. 1994. Early Pleistocene Hominid Foraging Strategies Along the Ancestral Omo River at Koobi Fora, Kenya. *Journal of Human Evolution* 27 (1): 247–266.
- Bunn, Henry T., Ellen M. Kroll, Stanley H. Ambrose, Anna K. Behrensmeyer, Lewis R. Binford, Robert J. Blumenschine, Richard G. Klein, Henry M. McHenry, Christopher J. O'Brien, and J.J. Wymer. 1986. Systematic Butchery by Plio/Pleistocene Hominids at Olduvai Gorge, Tanzania. *Current Anthropology* 27 (5): 431–452.
- Byrne, Richard W. 1997. The Technical Intelligence Hypothesis: An Additional Evolutionary Stimulus to Intelligence? In *Machiavellian Intelligence II: Extensions and Evaluations* 2, ed. A. Whiten and R. Byrne, 289. Cambridge: Cambridge University Press.
- Byrne, Richard W. 2000. Evolution of Primate Cognition. *Cognitive Science* 24 (3): 543–570.
- Calcott, B. 2008. Lineage Explanations: Explaining How Biological Mechanisms Change. *The British Journal for the Philosophy of Science* 60 (1): 51–78.
- Coolidge, Frederick L., and Thomas Wynn. 2009. *The Rise of Homo Sapiens: The Evolution of Modern Thinking*. Hoboken, NJ: John Wiley & Sons.
- Cooper, William S. 2001. *The Evolution of Reason: Logic as a Branch of Biology*. Cambridge: Cambridge University Press.
- Cummins, D. 2003. The Evolution of Reasoning. In *The Nature of Reasoning*, ed. J. Leighton and R. Sternberg, 339–374. Cambridge: Cambridge University Press. <https://doi.org/10.1017/cbo9780511818714.013>.

- Darmstadter, Howard. 2013. Why Do Humans Reason? A Pragmatist Supplement to an Argumentative Theory. *Thinking & Reasoning* 19 (3–4): 472–487. <https://doi.org/10.1080/13546783.2013.802256>.
- Day, Rachel L., Kevin N. Laland, and F. John Odling-Smee. 2003. Rethinking Adaptation: The Niche-Construction Perspective. *Perspectives in Biology and Medicine* 46 (1): 80–95.
- de Heinzelin, Jean, J. Desmond Clark, Tim White, William Hart, Paul Renne, Giday WoldeGabriel, Yonas Beyene, and Elisabeth Vrba. 1999. Environment and Behavior of 2.5-Million-Year-Old Bouri Hominids. *Science* 284 (5414): 625–629.
- Domínguez-Rodrigo, Manuel, Ignacio de La Torre, Luis de Luque, Luis Alcalá, Rafael Mora, Jordi Serrallonga, and Victoria Medina. 2002. The ST Site Complex at Peninj, West Lake Natron, Tanzania: Implications for Early Hominid Behavioural Models. *Journal of Archaeological Science* 29 (6): 639–665.
- Dutilh Novaes, Catarina. 2012. *Formal Languages in Logic*. Cambridge: Cambridge University Press.
- Gallagher, Shaun. 2017. *Enactivist Interventions*. Oxford: Oxford University Press.
- Godfrey-Smith, Peter. 1996. *Complexity and the Function of Mind in Nature*. Cambridge: Cambridge University Press.
- Godfrey-Smith, Peter. 2002. Environmental Complexity and the Evolution of Cognition. In *The Evolution of Intelligence*, ed. Robert Sternberg and J. Kaufman, 233–249. Mahwah, NJ: Erlbaum.
- Godfrey-Smith, Peter. 2017. Complexity Revisited. *Biology & Philosophy* 32 (3): 467–479. <https://doi.org/10.1007/s10539-017-9569-z>.
- Goren-Inbar, Naama, Nira Alperson, Mordechai E. Kislev, Orit Simchoni, Yoel Melamed, Adi Ben-Nun, and Ella Werker. 2004. Evidence of Hominin Control of Fire at Geshur Benot Yaaqov, Israel. *Science* 304 (5671): 725–727.
- Harmand, Sonia, Jason E. Lewis, Craig S. Feibel, Christopher J. Lepre, Sandrine Prat, Arnaud Lenoble, Xavier Boës, et al. 2015. 3.3-Million-Year-Old Stone Tools From Lomekwi 3, West Turkana, Kenya. *Nature* 521 (7552): 310–315. <https://doi.org/10.1038/nature14464>.
- Hay, Richard LeRoy. 1976. *Geology of the Olduvai Gorge: A Study of Sedimentation in a Semiarid Basin*. Berkeley, CA: University of California Press.
- Heyes, Cecilia. 2012. New Thinking: The Evolution of Human Cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences* 367 (1599): 2091–2096. <https://doi.org/10.1098/rstb.2012.0111>.
- Heyes, Cecilia M. 2018. *Cognitive Gadgets: The Cultural Evolution of Thinking*. Cambridge, MA: The Belknap Press of Harvard University Press.
- Hodder, Ian. 2012. *Entangled*. Hoboken, NJ: John Wiley & Sons.
- Hodder, Ian. 2014. The Entanglements of Humans and Things: A Long-Term View. *New Literary History* 45 (1): 19–36. <https://doi.org/10.1353/nlh.2014.0005>.
- Hutchins, Edwin. 1999. Cognitive Artifacts. In *The MIT Encyclopedia of the Cognitive Sciences*, ed. Robert A. Wilson and Frank C. Keil. Cambridge, MA: MIT Press.
- Jeffares, Ben. 2010. The Evolution of Technical Competence: Strategic and Economic Thinking. In *Proceedings of the Conference of the Australasian Society for Cognitive Science*, ed. W. Christensen, E. Schier, and John Sutton, 162–169. Sydney: Macquarie Centre for Cognitive Science. <https://doi.org/10.5096/ascs200925>.
- Jeffares, Ben. 2013. Back to Australopithecus: Utilizing New Theories of Cognition to Understand the Pliocene Hominins. *Biological Theory* 9 (1): 4–15. <https://doi.org/10.1007/s13752-013-0146-7>.
- Johnson, Mark. 2017. *Embodied Mind, Meaning, and Reason*. Chicago, IL: University of Chicago Press.
- Joulian, Frédéric. 1996. Comparing Chimpanzee and Early Hominid Techniques: Some Contributions to Cultural and Cognitive Questions. In *Modelling the Early Human Mind*, ed. Paul Mellars and Kathleen Gibson, 173–189. Cambridge: McDonald Institute for Archaeological Research.
- Kappelman, John. 1996. The Evolution of Body Mass and Relative Brain Size in Fossil Hominids. *Journal of Human Evolution* 30 (3): 243–276.
- Laden, Greg, and Richard Wrangham. 2005. The Rise of the Hominids as an Adaptive Shift in Fallback Foods: Plant Underground Storage Organs (USOs) and Australopithec Origins. *Journal of Human Evolution* 49 (4): 482–498.
- Laland, Kevin N., and Gillian R. Brown. 2006. Niche Construction, Human Behavior, and the Adaptive-Lag Hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews* 15 (3): 95–104.
- Laland, Kevin N., John Odling-Smee, and Marcus W. Feldman. 2000. Niche Construction, Biological Evolution, and Cultural Change. *Behavioral and Brain Sciences* 23 (1): 131–146. <https://doi.org/10.1017/s0140525x00002417>.

- Lamb, Trevor D., Shaun P. Collin, and Edward N. Pugh. 2007. Evolution of the Vertebrate Eye: Opsins, Photoreceptors, Retina and Eye Cup. *Nature Reviews Neuroscience* 8 (12): 960–976. <https://doi.org/10.1038/nrn2283>.
- Leonard, William R., and M.L. Bobertson. 2000. Ecological Correlates of Home Range Variation in Primates: Implications for Hominid Evolution. In *On the Move: How and Why Animals Travel in Groups*, ed. P.A. Garber and S. Boinski. Chicago, IL: University of Chicago Press.
- Leonard, William R., and Marcia L. Robertson. 1997. Comparative Primate Energetics and Hominid Evolution. *American Journal of Physical Anthropology* 102 (2): 265–281.
- Leroi-Gourhan, André. 1965. *Le Geste Et La Parole*. Paris: Albin Michel.
- Malafouris, Lambros. 2013. *How Things Shape the Mind*. Cambridge, MA: MIT Press.
- Marwick, Ben. 2003. Pleistocene Exchange Networks as Evidence for the Evolution of Language. *Cambridge Archaeological Journal* 13 (1): 67–81. <https://doi.org/10.1017/s0959774303000040>.
- McHenry, Henry M. 1992. Body Size and Proportions in Early Hominids. *American Journal of Physical Anthropology* 87 (4): 407–431.
- Meldrum, D.Jeffrey, and Charles E. Hilton. 2004. *From Biped to Strider: The Emergence of Modern Human Walking, Running, and Resource Transport*. Berlin: Springer.
- Menary, Richard. 2007. *Cognitive Integration*. London: Palgrave Macmillian.
- Menary, Richard. 2015. Mathematical Cognition: A Case of Enculturation. In *Open MIND*, ed. Thomas Metzinger and Jennifer M. Windt, 1–20. Mainz: Johannes Gutenberg Universität Mainz.
- Mercier, Hugo. 2013. The Function of Reasoning: Argumentative and Pragmatic Alternatives. *Thinking & Reasoning* 19 (3–4): 488–494. <https://doi.org/10.1080/13546783.2013.819036>.
- Mercier, Hugo, and Dan Sperber. 2011. Why Do Humans Reason? Arguments for an Argumentative Theory. *The Behavioral and Brain Sciences* 34 (02): 57–74. <https://doi.org/10.1017/s0140525x10000968>.
- Mercier, Hugo, and Dan Sperber. 2017. *The Enigma of Reason*. Cambridge, MA: Harvard University Press.
- Nilsson, D.E. 2013. Eye Evolution and Its Functional Basis. *Visual Neuroscience* 30 (1–2): 5–20. <https://doi.org/10.1017/s0952523813000035>.
- Norman, Andy. 2016. Why We Reason: Intention-Alignment and the Genesis of Human Rationality. *Biology & Philosophy* 31 (5): 685–704. <https://doi.org/10.1007/s10539-016-9532-4>.
- Ohel, M. 1984. Spatial Management of Hominid Groups at Olduvai: A Preliminary Exercise. *Paleoecology of Africa* 14: 125–146.
- O'Madagain, Cathal. 2019. Is Reasoning Culturally Transmitted? *Teorema: Revista Internacional De Filosofia* 38 (1): 107–120.
- O'Madagain, Cathal, and Michael Tomasello. 2019. Joint Attention to Mental Content and the Social Origin of Reasoning. *Synthese* 12 (4): 1–22. <https://doi.org/10.1007/s11229-019-02327-1>.
- Osvath, Mathias, and Peter Gärdenfors. 2004. Oldowan Culture and the Evolution of Anticipatory Cognition. *Lund University Cognitive Studies* 122: 1–16.
- Over, David. 2004. Rationality and the Normative/Descriptive Distinction. In *Blackwell Handbook of Judgement and Decision Making*, ed. Derek J. Koehler and Nigel Harvey, 3–18. Oxford: Blackwell Publication.
- Overmann, Karenleigh A. 2017. Thinking Materially: Cognition as Extended and Enacted. *Journal of Cognition and Culture* 17 (3–4): 354–373. <https://doi.org/10.1163/15685373-12340012>.
- Plummer, Thomas. 2004. Flaked Stones and Old Bones: Biological and Cultural Evolution at the Dawn of Technology. *American Journal of Physical Anthropology Suppl* 39 (January): 118–164.
- Potts, Richard. 1984. Home Bases and Early Hominids. *American Scientist* 72: 338–347.
- Richardson, Robert C. 2008. *Evolutionary Psychology as Maladapted Psychology*. Cambridge, MA: MIT Press.
- Rouse, Joseph. 2015. *Articulating the World*. Chicago, IL: University of Chicago Press.
- Santibáñez Yáñez, Cristián. 2015. Steps Towards an Evolutionary Account of Argumentative Competence. *Informal Logic* 35 (2): 167–182. <https://doi.org/10.22329/il.v35i2.4115>.
- Seitz, Fabian. 2020. A mind selected by needs. *Acta Analytica*. <https://doi.org/10.1007/s12136-020-00421-5>.
- Semaw, Sileshi. 2000. The World's Oldest Stone Artefacts From Gona, Ethiopia: Their Implications for Understanding Stone Technology and Patterns of Human Evolution Between 2.6–1.5 Million Years Ago. *Journal of Archaeological Science* 27 (12): 1197–1214.
- Semaw, Sileshi, Michael J. Rogers, Jay Quade, Paul R. Renne, Robert F. Butler, Manuel Dominguez-Rodrigo, Dietrich Stout, William S. Hart, Travis Pickering, and Scott W. Simpson. 2003.

- 2.6-Million-Year-Old Stone Tools and Associated Bones From OGS-6 and OGS-7, Gona, Afar, Ethiopia. *Journal of Human Evolution* 45 (2): 169–177.
- Sober, Elliott. 1981. The Evolution of Rationality. *Synthese* 46 (1): 95–120.
- Stenning, Keith, and Michiel van Lambalgen. 2008. *Human Reasoning and Cognitive Science*. Cambridge, MA: MIT Press.
- Sterelny, Kim. 2012a. *The Evolved Apprentice*. Cambridge, MA: MIT Press.
- Sterelny, Kim. 2012b. Language, Gesture, Skill: The Co-Evolutionary Foundations of Language. *Philosophical Transactions of the Royal Society B: Biological Sciences* 367 (1599): 2141–2151. <https://doi.org/10.1098/rstb.2012.0116>.
- Sterelny, Kim. 2016a. Deacon's Challenge: From Calls to Words. *Topoi* 35 (1): 271–282. <https://doi.org/10.1007/s11245-014-9284-1>.
- Sterelny, Kim. 2016b. Cumulative Cultural Evolution and the Origins of Language. *Biological Theory* 11 (3): 173–186. <https://doi.org/10.1007/s13752-016-0247-1>.
- Sterelny, Kim. 2017. Language: From How-Possibly to How-Probably. In *The Routledge Handbook of Evolution and Philosophy*, ed. Richard Joyce. Abingdon: Routledge.
- Sterelny, Kim, and Ben Jeffares. 2010. Rational Agency in Evolutionary Perspective. In *A Companion to the Philosophy of Action*, ed. Timothy O'Connor and Constantine Sandis, 374–383. Oxford: Wiley-Blackwell.
- Sutton, John. 2010. Exograms and Interdisciplinarity: History, the Extended Mind, and the Civilizing Process. In *The Extended Mind*, ed. Richard Menary, 189–225. The MIT Press. <https://doi.org/10.7551/mitpress/9780262014038.003.0009>.
- Tomasello, Michael. 2014. *A Natural History of Human Thinking*. Cambridge, MA: Harvard University Press. <https://doi.org/10.2307/j.ctt6wpq11>.
- Unger, Peter S., Frederick E. Grine, and Mark F. Teaford. 2006. Diet in Early Homo: A Review of the Evidence and a New Model of Adaptive Versatility. *Annual Review of Anthropology* 35: 209–228.
- Walker, Alan, and Richard E. Leakey. 1993. *The Nariokotome Homo Erectus Skeleton*. Cambridge, MA: Harvard University Press.
- Wood, Bernard. 1992. Early Hominid Species and Speciation. *Journal of Human Evolution* 22 (4–5): 351–365.
- Wynn, Thomas. 2002. Archaeology and Cognitive Evolution. *The Behavioral and Brain Sciences* 25 (3): 389–402. **(discussion 403–38)**.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.