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The Evolutionary Psychology of Extraterrestrial Intelligence: Are There Universal Adaptations in Search, Aversion, and Signaling?

Peter M. Todd¹ · Geoffrey F. Miller²

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Abstract

To understand the possible forms of extraterrestrial intelligence (ETI), we need not only astrobiology theories about how life evolves given habitable planets, but also evolutionary psychology theories about how intelligence emerges given life. Wherever intelligent organisms evolve, they are likely to face similar behavioral challenges in their physical and social worlds. The cognitive mechanisms that arise to meet these challenges may then be copied, repurposed, and shaped by further evolutionary selection to deal with more abstract, higher-level cognitive tasks such as conceptual reasoning, symbolic communication, and technological innovation, while retaining traces of the earlier adaptations for solving physical and social problems. These traces of evolutionary pathways may be leveraged to gain insight into the likely cognitive processes of ETIs. We demonstrate such analysis in the domain of search strategies and show its application in the domains of emotional aversions and social/sexual signaling. Knowing the likely evolutionary pathways to intelligence will help us to better search for and process any alien signals from the search for ETIs (SETI) and to assess the likely benefits, costs, and risks of humans actively messaging ETIs (METI).

Keywords Aversions · Evolutionary psychology · Extraterrestrial intelligence · METI (messaging extraterrestrial intelligence) · Search strategies · SETI (search for extraterrestrial intelligence) · Social signaling

Introduction

Evolution shapes not just bodies, but minds. Just as evolutionary biology can help us understand the likely physical features of extraterrestrial life-forms, evolutionary psychology and behavioral ecology can help us understand the likely cognitive and communicative abilities of extraterrestrial intelligence (ETI). This is because these latter two fields

use a rich toolbox of theories incorporated from biology, economics, and other disciplines that can illuminate a wide range of cognitive and communicative adaptations across a wide range of species. The key theories include optimal foraging theory, life history theory, host-parasite and predator-prey coevolution theory, sexual selection theory, and signaling theory. Beyond the details of terrestrial DNA-based life, these theories can be generalized to apply at a more abstract and universal level to life evolved elsewhere. Yet very little work on ETI so far has capitalized on the potential of such ideas to inform our expectations about alien psychologies.

All terrestrial organisms have evolved to solve concrete physical problems such as finding constituent chemicals, energy sources, and shelter, and avoiding threats such as predators, parasites, and toxins. The more intelligent species have evolved to meet particular social and sexual challenges as well, such as trading favors and attracting mates. And a few species appear to have evolved cognitive mechanisms for dealing with more abstract information-processing challenges, including navigating rich semantic spaces of concepts and communicating such concepts with others. The space of possible cognitive mechanisms that could support

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✉ Peter M. Todd
pmtodd@indiana.edu

Geoffrey F. Miller
gfmiller@unm.edu

¹ Cognitive Science Program and Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN, USA

² Department of Psychology, University of New Mexico, Albuquerque, NM, USA

such general intelligence might seem vast and unconstrained, making it hard to predict the likely psychology of ETIs. Yet, as we will argue, in even the most abstract cognitive mechanisms, we can often see traces of the earlier adaptations for solving physical and social problems from which they evolved.

Evolutionary Background

If we observe an organism moving around, searching for resources, avoiding dangers, and displaying signals to attract or warn others, we often feel that we can understand its motives and strategies (Barrett et al. 2005). But if we encountered an alien intelligence thinking about abstract problems, searching for good ideas, rejecting toxic ideologies, and communicating its findings to allies or rivals, we may worry that we have no basis for understanding its motives and strategies.

That reaction is too pessimistic, ignoring some deep principles of cognitive evolution that scientists can leverage to understand other intelligent species. These principles may well prove universal across very different life-forms with different kinds of habitats, genetic systems, biochemistries, and body forms. We expect that cognitive evolution is predictable in certain domains, and that studying these domains—including search strategies, emotional aversions, and social/sexual signaling—can help guide our understanding of ETI psychology. There are good reasons from ecological and evolutionary theory to expect that most intelligent extraterrestrial organisms will evolve to meet analogs of many of the same challenges, selecting for functionally analogous cognitive abilities. For example, while “shelter” on the African savanna may mean shade beneath an acacia tree, on the sea-floor of a Europa-like moon it might mean protection from tidal flexing convection currents under a salty outcropping, but the appropriate search strategies for organisms hoping to find each type of shelter may be similar.

Yet we can do more than just consider cases of convergent evolution, where different species evolve independently to solve similar challenges in similar ways. We as scientists can jumpstart our understanding of the *cognitive* adaptations of other intelligent life-forms by studying their—and our human—*behavioral* adaptations for dealing with challenges in the physical world and the social/sexual world. In particular, we can analyze the evolutionary pathways that lead to some of the challenges faced by intelligent organisms: because evolution often reworks old solutions to solve new problems, some of the familiar themes from behavioral adaptations for dealing with physical, social, and sexual challenges may be recognizable in the cognitive adaptations of intelligent species.

Why look to past adaptations for clues to current cognitive mechanisms, rather than just deriving the theoretically expected strategies for the problems those cognitive mechanisms may (approximately) solve? Reproductive success is relative, so evolution is often satisfied with good-enough solutions to current problems. You do not have to be perfect; you just have to be better than your rivals. So, evolution does not build superhuman (or super-alien) minds that gather all available information and process it using strictly rational procedures to yield mathematically optimal solutions, as in rational choice models of *Homo economicus*. Rather, evolution often develops quick-and-dirty heuristics that allow good-enough decisions. Humans and other animals evolved to use various simple heuristics that operate within the real-world constraints of limited time, limited information, and limited brainpower to yield approximate, rather than optimal, solutions to the problems they face (Gigerenzer et al. 1999, 2011). It may be possible to do better, but the marginal benefits may not outweigh the marginal costs.

We argue that many cognitive heuristics were adapted from behavioral mechanisms that evolved first to deal with the challenges of the physical environment. Adaptations for physical tasks such as finding food or avoiding parasites may later evolve to deal with more abstract, strategic social and sexual tasks in group-living species that include competitive mating markets (and there are good reasons to expect that most intelligent species including ETIs evolve from social, sexually reproducing, group-living species; Miller 2000b). Then, these sociosexual adaptations may be copied, repurposed, and shaped by further selection to deal with more abstract, higher-level cognitive tasks such as conceptual reasoning, symbolic communication, technological innovation, and intellectual curiosity—while still retaining design quirks that hint at their ancestral origins and functions. This “cognitive turn” from physical domains through sociosexual domains to abstract cognitive domains characterizes not just the evolution of terrestrial social primates over the last 50 million years or more, but also could likely characterize the emergence of many ETIs.

Such adaptive pathways may be the most typical route for alien life-forms to reach the general intelligence levels necessary for large civilizations and advanced technologies, because evolution often follows a quick and easy path, acting as a tinkerer or “backwoods mechanic” (Wimsatt 2007) and building new things from old parts that are already on hand. Given new selection pressures, adaptations that evolved originally to serve one function are often copied and repurposed to serve new functions. Adaptations that capitalize on existing resources such as genomic regulatory networks, neurodevelopmental pathways, neuromodulator systems, and computational modules (or their alien equivalents) can evolve more quickly than solutions arising *de novo*. In a variety of complex adaptive systems with modular components,

new functions get added by reusing and modifying existing features. Programmers patch together new code using libraries of existing code, rather than writing every line from scratch. Companies enter new markets and create new products by patching together existing employees, teams, and intellectual property, rather than hiring all-new workers and inventing all-new brands. Likewise, evolution patches together new mental adaptations using genomic libraries and developmental and cultural scaffolding of existing information-processing machinery. Thus, cognitive adaptations may be a useful level of analysis for considering the likely origins and functions of thoughts, feelings, and preferences in other intelligent species.

Evolutionary psychology and behavioral ecology are relevant to understanding alien intelligence, just as evolutionary biology is to understanding alien life-forms. Further, adaptive pathways from physical through social to abstract cognitive domains may be common ways for alien intelligence to evolve. In the rest of this article, we describe a specific adaptive pathway in the domain of searching for good things (such as food, mates, and ideas); we briefly introduce two other domains, avoiding bad things (through anti-pathogen, sexual, moral, and intellectual disgust) and signaling one's own traits to others (to deter predators, intimidate rivals, or attract mates), which are described in more detail in Todd and Miller (2017). We will then consider the implications of evolutionary extraterrestrial psychology and these three domains for the search for extraterrestrial intelligence (SETI) in astrobiology, and in messaging ETIs (METI).

Our focus here is on the initial, naturally evolved forms of ETI, before ETIs consciously shape their further evolution through genetic selection or cognitive engineering, and before they invent artificial intelligences, autonomous robots, self-replicating spaceships, and so on. Natural evolution of minds will rely heavily on reuse of existing adaptations, but rational engineering of genetically engineered or artificial intelligence may break free of traditional adaptation pathways to find globally optimal (or at least better and different) information-processing methods, as humans are beginning to accomplish using methods such as Bayesian networks and deep learning. However, we expect that our arguments will apply to quite a range of naturally evolved intelligences, including socially distributed intelligences like those of eusocial insects (cf. Dornhaus 2017).

Search Strategies

Animals interact with their environments. They evolve to approach the things that promote their reproductive success (e.g., food, shelter, mates) and to avoid the things that threaten their reproductive success (e.g., predators, pathogens, rivals). So, they need to find and perceive all kinds

of “fitness affordances”—things that “afford” fitness benefits or impose fitness costs (Gibson 1979; Miller 2007). Food affords eating; mates afford breeding. Initially these fitness affordances are concrete physical objects (e.g., food, predators). Then, some organisms evolve to register social and sexual affordances (e.g., kin, friends, rivals, mates, offspring). Finally, the most intelligent information-sharing organisms evolve to pay attention to more abstract cognitive affordances (e.g., surprises, memories, news, arguments, evidence, morals, science).

But fitness affordances such as food and mates can be hard to find, because they are spatially distributed, and other animals are looking for them too. So animals need search strategies that maximize the rate of encountering good things while minimizing the energy costs and risks of movement. Optimal foraging theory in biology has analyzed this problem for decades (Bell 1991). A key insight was that many good things in nature are not uniformly distributed, but are clustered into patches—lakes where gazelles can drink, herds of gazelles that lions can attack, leks of male birds that females can mate with. Patches arise partly because inorganic resources are unevenly distributed (“spatially autocorrelated”), but especially because organic resources (plants and animals) arise through local reproduction. This patchy structure of fitness affordances means that animals face tradeoffs between exploiting an existing patch of good things versus exploring the environment to find new patches of good things. Spatial autocorrelation of resources is likely to hold in any extraterrestrial environment that evolves life, whether on the surface of a rocky planet, under the ice crust of a tectonic moon, or in the turbulence of a gas giant.

Search strategies are ways for animals to organize their approach and avoidance behavior, exploring to find patches of useful resources, exploiting them until they are depleted, and exploring for new patches. These explore/exploit search strategies evolve initially to guide search through physical space for physical resources such as food and shelter, but then they can be generalized to the sociosexual domain (e.g., searching for attractive mates, reliable friends, or savvy mentors), and then they can even be applied to more abstract informational domains (e.g., searching episodic memory, exploring strategic alternatives, testing hypotheses, Googling “Europa tectonic plates”).

Perhaps the earliest behavioral adaptations were for finding sources of energy—food, light, and heat. For a mobile organism, the simplest explore/exploit search strategy is: if the energy resource is present, stay put and use it; if not, then move on to find it (a “win-stay/lose-shift” strategy). Just how to “move on” will depend on the spatial (and temporal) structure of the resource environment and on the organism's ability to perceive, remember, and understand its structure (Bell 1991). In terms of where to go, if resources are distributed in all directions, then move in any direction; if not,

then determine a likely direction (e.g., a chemical gradient of prey smell, an acoustic gradient of mating calls, or visual cues such as spoor or trails.) If plant or animal resources grow back over time, then go back to where resources have been found in the past.

How far should animals go when searching? This depends on the resource structure of the environment and the organism's sensory and movement capabilities. Because movement in space is energetically costly, it will be minimized where possible. So, if resources are likely to be nearby, then look for them nearby without moving much. This works well when resources are uniformly distributed, as they may have been in early terrestrial ecosystems characterized by microbial mats on sea floors. But many environments have patchy distributions of resources, with regions of high resource concentration separated by relatively resource-empty spaces. Metazoans grazing on microbial mats, for instance, would become patches of high resource density for scavengers when they died. Flowers growing in clumps become a patch for foraging bees, and the bees' nest is a patch for honey-seeking mammals. (And at the interstellar scale, likely planets for hosting advanced civilizations may also come in patches; Di Stefano and Ray 2016). Organisms seeking such patchy resources need to move larger distances to get from one patch to another, but once they find a resource that may be in a patch, such as a nectar-rich flower, they should take smaller steps to find other resources likely to be nearby in the same patch without expending unnecessary movement energy.

Thus, once an organism finds a resource patch, it should switch from exploring—making larger moves through space—to exploiting—moving shorter distances within a patch to exploit more of the resource. At some point, though, the organism may deplete the easily found resource in the patch, for instance drinking the nectar from many of the flowers, and will have to decide whether to keep trying to exploit that patch or leave and look for another patch. This is the basic explore/exploit dilemma for organisms searching in patchy resource environments: exploring for new resources (during which energy is expended and resources are often not being taken in) versus exploiting existing resources (when resource intake declines as resources are depleted). Explore/exploit problems are found in a wide range of domains facing individuals and groups, and many behavioral strategies, heuristics, and mechanisms have arisen to address them (Hills et al. 2015).

The optimal way to solve the explore/exploit problem in foraging for patchy resources is to leave the current patch when its rate of return falls below the mean rate of return that would be obtained by optimally exploring and exploiting the whole distribution of patches in the environment (as specified by the marginal value theorem; Charnov 1976). That is, the forager should leave a patch when it could do

better by going elsewhere, taking into account the costs of traveling to the next patch. Typical evolved adaptations that enable a variety of species to come close to optimal explore/exploit performance include simple heuristics such as leaving a patch when a certain amount of time has elapsed since the last resource item was found (a “giving-up time” rule), or performing “area-restricted search” in which each resource item found makes the searcher focus on the local area (e.g., by taking smaller steps or higher-angle turns to stay nearby), but elapsing time without finding a resource leads to a gradual return to global exploration (e.g., larger steps and less turning) (Stephens and Krebs 1986; Bell 1991).

Hominids evolved in environments (e.g., the African savanna) with mostly patchy resources, such as watering holes, berry bushes, game animal herds, and clans of potential mates. This resulted in a general expectation among modern humans that resources tend to come in patches (Wilke and Barrett 2009), and a set of psychological mechanisms to decide how to search or forage among them. In a computer task that mimicked foraging in space, people encountered a sequence of ponds (patches) containing depletable stocks of fish that they could catch. They had to decide when to leave and move on to the next one; decisions made using “giving-up time” mechanisms produced near-optimal rates of finding resources (Hutchinson et al. 2008). Tribal people's foraging behavior in the wild shows similar patterns (Winterhalder and Smith 2000).

Explore/exploit heuristics are crucial for adaptive search in nonspatial domains as well (Hills et al. 2015). In the social search for mates, individuals—whether female sage grouse searching among males in a lek, or humans searching among potential dates on the OkCupid website—must balance how much time they spend gathering information about each potential mate against the benefits of moving on to evaluate potentially better prospects (Saad et al. 2009). Individuals may also use area-restricted search at the more abstract level of phenotypic similarity, for example searching first for a “nearby” mate who is similar in appearance or personality to an opposite-sex parent (Todd and Miller 1993), and then, if no such “close” mates are found, relaxing those similarity preferences to explore the space of possible phenotypes more broadly (Hills and Todd 2008a). For species that pair-bond, time spent in a sexual relationship may be analogous to time spent exploiting a food patch, with mate switching analogous to searching for a new food patch.

At the cognitive level, we find similar explore/exploit heuristics. In visual search tasks, people have to control their eye movements and attention to find target items that appear in clusters, and searching within clusters versus switching between clusters follows patterns similar to foraging in space (Wolfe 2013). Further, similar decision strategies are used by humans searching for information in the external environment—e.g., when “information foraging” on the Web,

people leave a “local patch” of closely linked Web pages when they decide that its value (or “information scent”) has fallen below what they could find from searching globally elsewhere (Pirolli 2007). People also seem to search for information internally in memory according to expectations from optimal foraging theory. For example, when asked to “name all the animals you can think of in three minutes,” people typically switch between exploiting local patches of conceptually related animals (e.g., “lion, tiger, puma, caracal”) and exploring globally for new categories of animals (e.g., pets, seafood, farm animals, mythological creatures, horror-movie aliens)—and they do this in ways that maximize their success, as predicted by the marginal value theorem (Hills et al. 2012).

These results suggest that related mechanisms guide organisms’ search for resources in physical space, search for partners in social space, and search for information in cognitive spaces (see Todd et al. 2012b, for an overview). Is this the result of adaptations being sequentially copied, repurposed, and refined from mechanisms for physical to social to information environments, or are these cases of convergent evolution of similar mechanisms given similar optimization problems across the three domains? One clue comes from the neurophylogeny of search strategies. Hills (2006) argued that dopamine-driven mechanisms guiding the search for food were the evolutionary basis of mechanisms guiding search for other resources, including attention-based search for information in the external environment and executive control of internal search for plans and solutions during goal-driven cognition. This argument is supported by a priming study that suggests a common underlying mechanism for external foraging and internal information search, possibly based on early dopaminergic search circuitry. In this study, people who engaged in more local exploitation in a spatial foraging task—staying longer in each spatial patch of resources—also exploited patches in memory longer in a more abstract anagram puzzle task (Hills et al. 2008b).

Furthermore, it does not seem inevitable that people should search through memory in ways that mirror search through physical space—for instance, searching in an area-restricted manner, looking at nearby points first. In spatial search, this happens partly because resources are patchy, and partly because locomotion is energetically expensive. By contrast, in memory search, useful information might not be meaningfully “nearby” within associative patches, and the costs of switching memory patches might be negligible. If this turns out to be the case, then the fact that humans nonetheless often use area-restricted search in memory suggests adaptation of search strategies from physical space to conceptual spaces. This would be consistent with a cognitive repurposing view (that area-focused search in memory builds upon area-focused search through habitats) rather

than a cognitive convergence view (that area-focused search works because it is effective in both domains, memory and habitat). However, the repurposing from habitat search would not have worked if it had not been at least somewhat effective in the new domain of memory.

Once a positive fitness affordance such as a food item has been found through a search strategy, it must usually be processed in some way to yield its latent fitness benefits such as nutrients. Organisms evolve to control complex sequences of physical movements for processing fitness affordances from their raw state into more useful forms. Sometimes this involves sequences of disassembly, as when a predator dismembers prey into smaller, more easily swallowed chunks. Sometimes this involves sequences of assembly, as when a weaverbird combines grasses and twigs into safe nests for offspring. These sequencing mechanisms may often be copied and then adapted to the sociosexual domain (e.g., progressing through multistep courtship rituals, threat displays, and offspring-grooming bouts) and then to the cognitive and communicative domains (e.g., speaking sentences, telling stories, pursuing if-then reasoning, planning space flights; see Holloway (1969) for suggestions that the forward-looking planning aspects of toolmaking and language may have been copied and modified from earlier hierarchical organizations of motor behavior).

Two Further Domains: Emotional Aversions and Social Signaling

Just as organisms evolve mechanisms for finding good things, they also evolve mechanisms for avoiding bad things. Larger, more complex organisms evolve to avoid infestation by smaller, faster-evolving parasites that impose costs, risks, and diseases. They do this partly through a physiological immune system (antibodies, cytokines, leukocytes, etc.) that fights pathogens once they have entered the body, and partly through a “behavioral immune system” based on emotional aversions such as disgust that helps individuals avoid exposure to pathogens in the first place. Anti-pathogen disgust works to prevent contact with pathogens such as salmonella bacteria in rotting meat, the measles virus in clan-mates, and syphilis bacteria in potential mates. It achieves this by coding cues of infectiousness, such as the smell of decay or the appearance of skin lesions. Disgust is at its core a mechanism for avoiding parasites and diseases (Oaten et al. 2009; Rozin and Todd 2016): it focuses on things likely to harbor pathogens (meat, blood, feces, vermin, lesions); it uses a “logic of contagion” that embodies awareness that invisible microbes can multiply exponentially in the body; and it provokes physical distancing, self-grooming, and social ostracism. Host-parasite coevolution is a universal feature of organic life, so any intelligent aliens are likely to

have evolved some anti-pathogen disgust to defend against their ancestral pathogens and parasites. Disgust also appears to have been adapted for use in sexual and social domains (Tybur et al. 2013). Sexual disgust is triggered by certain sex acts and potential mates that could be dangerous. Most complex animals with nervous systems on Earth reproduce sexually using some mate selectivity, and there are good theoretical reasons why intelligent aliens are likely to be sexually selective as well (Miller 2000b), so aliens are likely to have evolved sexual disgust towards certain kinds of acts and mates. In the social domain, moral disgust is triggered by bad behavior such as lying, cheating, stealing, assaulting, raping, or killing (Russell and Giner-Sorolla 2013). At a more abstract level, we propose that “intellectual disgust” may have evolved to avoid exposure to bad ideas, malicious gossip, biased hearsay, stupid memes, logical fallacies, alternative facts, and “fake news.” Once an intelligent species evolves the ability to transmit and receive ideas through symbolic communication, it may benefit from adapting other forms of disgust into some form of intellectual disgust, to protect cognitive systems from epistemic corruption.

Another domain likely to foster reuse of adaptations is that of social signaling—advertising one’s qualities as fitness affordances to other organisms, for example, one’s excellence as a fertile mate, a formidable enemy, or an elusive prey. Fitness indicators are exaggerated traits such as the peacock’s tail or the elk’s antlers that evolve to signal the fitness of one organism to another. Fitness indicators rely on game-theoretic signaling principles: they must be large, costly, complex, and/or precise so that they are honest, or else other organisms would evolve to ignore them (Zahavi 1975; Miller 2012). Consequently, many fitness indicators take conspicuous, unfakeable physical forms, including physical signals of attractiveness to mates (sexual ornaments like bird plumage) and formidability to rivals (weapons like teeth, horns, and antlers; Zahavi 1975). In our lineage, sexual selection has gone a step further, favoring still more abstract signals based on individual mental traits (Miller and Todd 1998). These “mental fitness indicators” include intelligence (Miller 2000c), language (Miller 2002), and creativity and art (Miller 2000a; Haselton and Miller 2006). Given sexual reproduction and genetic variation, there are incentives for organisms to select their mates carefully by paying attention to fitness indicators—and for the fitness indicators to become ever larger, more complex, more precise, and more attractive. Cognitive and communicative abilities make especially informative fitness indicators because their underlying computational systems must be especially complex and precise, so uniquely vulnerable to harmful mutations, uniquely informative about fitness, and uniquely likely to get caught up in a signaling arms race that drives a runaway elaboration of intelligence (Miller 2000a, b, 2002). Thus, we can expect that extraterrestrial

intelligence is most likely to emerge among life-forms that are sexually reproducing, choosy about their mates, and a bit obsessed with each other’s mental fitness indicators—in a word, “sapiosexual.” Indeed, the progression from physical to behavioral to social to cognitive signaling may be the mainspring of ETI evolution across many worlds, as it has been in human evolution.

Analyzing Pathways for ETIs

Analyzing adapted pathways should be useful in understanding ETIs, regardless of their form or habitat. This is because the information-processing mechanisms that evolved to deal with physical domains are not perfectly adaptable to social, sexual, or cognitive domains, owing to the different structures in these different domains. (The nature of the fit between decision mechanisms and information structures in different environmental domains is studied in the field of ecological rationality; see, e.g., Todd et al. 2012a.) Human minds are cobbled-together patchworks of mental adaptations that originally evolved for one set of purposes, but that in many cases were then modified for quite different purposes. ETI minds, at least as they originally evolved, are likely to be similar: a patchwork of reused adaptations piled upon adaptations. This section considers some examples of how this matters—how to leverage evolutionary theory to make better predictions about the likely cognitive quirks of ETIs.

For example, in the physical domain, material resources such as space, food, and shelter have lower value when they have to be divided among competitors. Playing with physical resources is a zero-sum game. But in the cognitive domain, informational resources such as news, scientific findings, and technical innovations can retain their value when shared with many individuals (though the originator may get the most prestige). Playing with ideas is often a positive-sum game. So, if intelligent species use physical-domain mental models to think about how resource sharing affects the value of information in the cognitive domain, they may tend to hoard ideas the way they hoard food. They will treat the world of shareable bits as if it were a world of non-shareable atoms—as we see evidence for in humans. In legal history, for example, it has taken centuries to adapt ancient principles concerning hard-to-share land (real estate property law) so they are suitable for easy-to-share ideas, brands, and patents (intellectual property law). Relatedly, intelligent species may adapt their spatial cognition for social cognition, and might make predictable errors, such as overestimating the mutuality of social closeness (if A likes B, B must like A), since spatial distances are commutative.

By considering which of the tools in a preexisting toolbox of mechanisms that evolved for an earlier set of problems

may be used and modified to solve a new set of problems, we can develop a candidate set of cognitive mechanisms that might be found in ETIs. This is the approach we take here, looking at the behavioral mechanisms originally evolved to deal with the physical world for possible ways of dealing with social, sexual, and cognitive worlds. In hindsight, some of the proposals may not seem surprising—of course one should search for more solutions to a problem that are similar or near to solutions that have already been found. But some of the commonalities among the domains may be missed without this sort of perspective, and the physical differences between humans and aliens may obscure deeper psychological similarities. Furthermore, without an evolutionary psychology framework that makes the “natural seem strange” (James 1890; quoted in Cosmides and Tooby 1997), the things that seem natural and obvious about our own species’ behavior may get overlooked when dealing with alien behavior generated by minds inhabiting very different morphologies, societies, and technologies.

Implications for Interacting with ETIs

What We Should Look for in ETI Signals (SETI)

Let us make the reasonable common assumption that any ETIs capable of contacting us or receiving our signals are much more advanced in their science. This means they have already understood for millennia everything that we have argued here about adaptation, search strategies, behavioral immune systems, and signaling strategies (assuming we are right about any of them). How would such knowledge guide their strategies for searching for (other) ETIs (that is, their own SETI), and for messaging other ETIs (that is, their METI)? And how should our knowing what they already know guide our own SETI and METI strategies? (Here we assume some ability on the part of receivers to understand the content of messages sent, though in some cases, e.g., signaling of formidability through high-powered transmissions from many beacons across several parsecs, appreciating the medium itself may be sufficient to get the message—cf. Wason 2014 on recognizing intelligence versus understanding content.)

Assuming they do not know much about whether their target audience is nice or nasty, strategically prudent ETIs would not want to send a signal that advertises the location of their home world or colonies, to avoid triggering the search strategies of any resource-hungry or aggressively curious aliens that might receive such a signal (Liu 2015). They would probably leave out any information about the coordinates or properties of their planet and star system, and they would use cryptic transmission technologies, distant

relays, and other subterfuges to obscure the true origins of their signals.

Prudent ETIs wishing to hold their audiences’ attention should avoid triggering the audiences’ behavioral immune systems, knowing that their messages should not be too disgusting. To minimize anti-pathogen disgust, they may not include visual depictions of their bodies, or information about their physical appearance, health issues, or parasites. To deter sexual disgust, they may avoid revealing details about their sexual ornamentation, courtship strategies, sexual behaviors, and mating systems. To avoid moral disgust, they may be very circumspect about their ethics and values. And to avoid intellectual disgust from potentially even more advanced civilizations, they may reveal only a few of their best-established theorems and empirical insights.

In terms of signaling, prudent ETIs should not communicate much about their formidability, such as their weapon capabilities or number of star systems colonized. They would not want to panic weaker audiences by appearing too formidable, but they would not want to seem easily exploitable to larger, more advanced civilizations. Again, the best strategy may be to give away the least possible information—just as many animals stay quiet in dark jungles.

All of this means that, without assuming that ETIs possess any deeper understanding of evolutionary psychology than current Earth scientists possess, we can make a good bet that ETIs doing interstellar signaling will include very little information about themselves, including their location, bodies, mating systems, ethics, science, or formidability. Even if they are feeling chatty, they may broadcast nothing more than “hey, here are some big prime numbers, just to show that we exist and we’re reasonably clever.”

This strategic analysis of how ETIs should construct interstellar signals, given a few evolutionary psychology insights, goes both ways: it should also apply to how we humans interpret any signals that we receive, and to how we design any signals that we send. In analyzing any ETI signals received, evolutionary game theory and signaling theory caution us to take nothing at face value. Most signaling on Earth has evolved to manipulate the behavior of receivers in the signaler’s own interests, treating the receivers’ nervous systems as an “extended phenotype” of the signaler, and not to altruistically convey useful information about the world (Krebs and Dawkins 1984; Bradbury and Vehrencamp 2011).

Given the superficially cooperative nature of human language, we look like a virtuous exception. However, most human verbal behavior is also centered around influence, rhetoric, social manipulation, and sexual seduction (Miller 2000a, 2002). Signaling theory also emphasizes that most biological signals function to intimidate rivals, deter predators, attract mates, or solicit help from parents and kin (Bradbury and Vehrencamp 2011). In interstellar relationships,

only the intimidating-rivals function is relevant: it would not be economical for aliens to hunt us (as opposed to our home-world) for food; they would be sexually disgusted to mate with us, and they would not be related enough to care about our welfare based on our genetic similarity. Further, when intimidating potential rivals, signal reliability is guaranteed more credibly by signal amplitude, precision, duration, and spatial distribution than by apparent signal content. The point of broadcasting a loud, intricate, long-lasting, widely repeated signal is not just to be detectable; it is to be impressive in a hard-to-fake way. Calculations about the detectability of radio or laser signals are less important in SETI than a serious signaling theory analysis of which messaging features would look most formidable given minimal background knowledge about the signalers. Thus, what alien messages may claim about their civilizations (e.g., “Don’t mess with us—we have 10 million heavy battle cruisers”) will be less informative than how many exawatts they burn to convey this message, how precisely modulated their signals are, how many millennia the signals are broadcast for, and how many star systems the same signal is being broadcast from.

Why We Should Not Yet Send Our Own Signals (METI)

Similar cautionary principles, grounded in evolutionary psychology and signaling theory, should apply even more strongly to any signals we humans send to aliens, in any messaging ETI (METI) program (see Johnson 2017 for an overview). A simple METI message of the type we are currently capable of sending announces to nearby ETIs that it is probably from a newly technological species that is still stuck on its ancestral home-world—and that the home-world is likely to be a habitable planet with enough organic resources to support a diverse biosphere. Astrobiologists have argued that most life anywhere will probably evolve on rocky planets, using carbon-based chemistry, plentiful water as a solvent, and a highly reactive oxygen atmosphere for fast metabolism. Those resources (habitable planet, organic molecules, water, oxygen) might be relatively rare and desirable as fitness affordances to any ETIs—to be taken by subterfuge, propaganda, or force. Thus, any METI-signaling species that has just recently developed a bit of science and technology is basically saying that they evolved quite recently on a big habitable planet with plentiful resources, they are naive enough to be broadcasting from their sacred home-world, and there is so little local competition for their resources that they have not yet been assimilated or exterminated by more advanced and prudent local rivals. In other words, a naive METI signal announces, “Here is a delectable treat—a home-world with valuable and easy-to-acquire resources, lightly guarded by a gullible young species.”

Moreover, as described earlier, life everywhere evolves to deal with patchy resources and to search for those resources efficiently, using the explore/exploit tradeoffs from optimal foraging theory. At the cosmic level, the limiting resources for supporting organic life (habitable planets, water, oxygen) are extremely patchy, and likely to be contested by life-forms that evolved using a similar biochemical basis in similar habitats. If interplanetary or local interstellar colonization is possible, any METI message from point X could be taken as evidence that there are likely to be other habitable planets near X. Thus, a METI message might suggest the availability of a whole patch of life-supporting worlds to be exploited, rather than just one treat. An understanding of search heuristics, and the deeply competitive (and possibly zero-sum) nature of evolved resource-exploitative strategies, should make us very reluctant to reveal any information at all about our location, whether in the explicit form of relative distances to nearby pulsars (as on the plaques intended for extraterrestrial communication on the Pioneer space probes launched in the early 1970s), or in subtler forms that would allow inferences about our location using other triangulation methods we cannot imagine yet.

Further, if we send a weak signal, we signal weakness. Any METI signal will likely be interpreted by aliens as either a credible signal of formidability, or not. (We would not be able to send credible signals of sexual attractiveness without knowing their mate preferences; we could not credibly send signals of potential for mutually beneficial trade in resources or ideas unless our science and technology closely matched theirs.) If we credibly signal high formidability, we position ourselves as a threat worth neutralizing. If we signal low formidability (intentionally or not), we announce our vulnerability and exploitability. So how do we signal that we are “just right” in terms of formidability—neither an imminent threat nor a bunch of exploitable simpletons—without having a good estimate of the ETI’s own level of formidability? We do not yet know—and this raises the concern that METI metaphorically changes our planet from a “nut,” an armored, unobtrusive, and often unnoticed seed, into a “fruit,” a seed with an accompanying resource packet that advertises its availability to frugivores, incentivizes their approach and exploitation, and hopes it will survive passage through their digestive system. And if we do not understand the capabilities and agendas of local frugivores, it is better to stay an acorn than show off as a papaya.

Even if a METI signal does not trigger resource envy in ETIs, it might provoke disgust—and disgusting animals often get squished by larger, stronger animals. If we share any biochemistry, phenotypic similarity, parasitic vulnerabilities, or pathogen transmission pathways with the receivers, we could provoke anti-pathogen disgust. If we reveal details about our sexuality, mating, or erotica, we will likely provoke sexual disgust, since the ETI’s mate preferences will

not match our phenotypes. If we reveal what we consider to be our highest ethical ideals, forms of effective altruism, and strategies for reducing avoidable suffering, we may fall far short of more advanced ETI morality and provoke moral disgust. And if we proudly display what we cherish as our most fascinating achievements in the arts, humanities, sciences, and religions, these might provoke intellectual disgust, and be treated as infectious memes deserving informational quarantine rather than as cultural achievements deserving serious analysis. Behavioral immune system theory suggests that if we include any detail about our bodies, mating systems, ethics, or ideas in our METI signals, we may incite disgust and abhorrence rather than curiosity and sympathy in ETIs.

And perhaps more bruising to our intellectual egos, our proudest cultural achievements conveyed through METI may not provoke intellectual disgust and meme-containment protocols, merely boredom. We just might not be that interesting to ETIs. If aliens have advanced science, that will likely include not just advanced physics but also advanced biology and behavioral sciences—including evolutionary signaling theory, evolutionary game theory, evolutionary psychology, and Darwinian aesthetics. They may already understand that the art, music, stories, humor, and other forms of creativity produced by most intelligent species are largely a set of signaling adaptations for attracting mates, friends, and status. What we consider the highest products of civilization and genius, they may see as just another set of trait-signaling adaptations with largely predictable themes and semi-random variations—especially if we are not the first species they detect.

Finally, considering our METI signaling from the perspective of signaling theory itself should make each of us more skeptical and self-conscious about our own motives for doing METI in the first place. Why do individuals really want to do METI—is it to signal human existence to ETIs, or to signal the individual's personal traits such as openness, optimism, and altruism to other people? Humans evolved in social and sexual circumstances that favored relentless gossip, creative showing-off, verbal courtship, and virtue-signaling (Miller 2000a), and we have irrepressible instincts for broadcasting our intelligence, personality traits, and moral virtues to anyone who will listen (think Twitter). Many of the rationales given for METI seem to tap into these trait-signaling instincts, so we should self-consciously assess whether our METI signaling motives spring from the desire to show off to each other, or the drive to communicate between intelligent civilizations.

Advocates of METI appear to want to show off to ETIs that humanity as a whole has the moral virtues of truth (honest message content), courage (signaling despite the risks), inclusiveness (reaching out to other life-forms despite our radically different natures), and reciprocity (transmitting, not just receiving). For instance, METI

International's (2016) Strategic Plan states, "By conducting a METI project, we will model a sense of fairness and responsibility in making contact with other life," and Zaitsev (2006) said that METI "can be thought of as a purely messianic, unselfish activity, seeking to help our neighbors learn, that they are not alone in the boundless Universe." Advocates often frame METI as the courageous and optimistic choice, and disparage critics as fearful and pessimistic (Shostak 2015). The former may be a more desirable signal to some human listeners, but any METI strategy that could impose global risks to our whole planet, and existential threats to our whole species, should get committed buy-in from everyone across the political spectrum, across countries, and across generations.

Indeed, some METI advocates have argued that if we are already "listening in the jungle" with SETI, we have a moral duty to "shout into the jungle" with METI: "We and every other ETI are morally obligated to realize together active and passive CETI [communication with extraterrestrial intelligence, i.e., SETI and METI]..." (Subotowicz et al. 1979, p. 205; quoted in Vakoch 2011). It is as if there is some cosmic reciprocity principle that demands tit-for-tat exchanges of honest information over vast distances between civilizations with wildly asymmetric forms and levels of power. The underlying thinking seems to be that we will not be admitted to the "galactic club" if we do not pass the initiation rite of taking the risk in signaling our virtues as good reciprocators. This kind of virtue-signaling is a reasonable strategy between partners with some common ground, as when human individuals are trying to attract mates or friends, or when nations demonstrate their good intentions to promote peace, trade, and other mutual benefits. But virtue-signaling only works if the signal receivers value the virtues that we offer, and see some potential for positive-sum interactions. So, what we consider altruistic information sharing, ETIs with different values may consider narcissistic noisemaking or foolhardy exploitability (see Barkow 2017 for related concerns).

Unfortunately, all human METI signals sent so far—including on the space probes Voyager and Pioneer, and from the radio telescopes at Arecibo and Eupatoria—exemplify these unconscious human trait-signaling instincts, rather than a conscious understanding of evolutionary psychology and signaling theory as applied to our interactions with ETIs. These METI signals also violate the precautionary principles described above for why we should not reveal our location, bodily form, technological (lack of) formidability, cultural creations, and so on. It is perhaps the most dangerous game any newly technological species could possibly play, and we do not even know the rules yet. By contrast, nuclear weapons are very dangerous, but at least the 1950s game theorists discovered that "mutually assured destruction" could deter global thermonuclear war fairly reliably.

Going forward, we should practice extreme caution, both in interpreting SETI messages, and in undertaking any METI projects. Evolutionary psychology and signaling theory are crucial additions to astrobiology for basing our SETI and METI strategies. Yet these sciences are only a few decades old, with major new principles and findings being discovered every year. We are nowhere near a mature level of understanding about patterns of cognitive evolution across humans, artificial intelligences (AIs), and ETIs. Perhaps in a few more centuries, we will know enough about adaptations, search heuristics, behavioral immune systems, fitness indicators, and other cognitive domains to have a little more confidence about how we should interpret or send interstellar messages. But until then, we think that SETI should be done very cautiously, with our intellectual-disgust radar on high alert to avoid potentially infectious memes, propaganda, and Trojan horses from ETIs.

As for METI, we think there is an urgent need for more serious risk analysis before any more messaging is considered; a global moratorium on METI (enforced at least as seriously as nuclear nonproliferation treaties) is appropriate in the meantime. We are still far from even an advanced-beginner understanding of evolutionary signaling theory as applied to exopsychology. Once we get to an intermediate-level understanding, maybe we will conclude that we missed out on a few centuries of benefits from benevolent ETIs. But we might instead realize that METI would have been a grave existential threat to humanity. If that happens, we hope our descendants can look back with the satisfaction of knowing that we did not broadcast our weakness and naiveté by sending weak and naive signals, before we had any idea how our well-intentioned virtue-signaling would be heard in the rest of the dark forest.

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