

A bottom-up approach with a clear view of the top:  
How human evolutionary psychology can inform adaptive behavior research

Geoffrey F. Miller  
School of Cognitive and Computing Sciences  
University of Sussex  
Falmer, Brighton BN1 9QH, England  
(Now at Department of Psychology, University of Nottingham;  
gfm@psychology.nottingham.ac.uk)

Peter M. Todd  
Department of Psychology  
University of Denver  
2155 S. Race Street  
Denver, CO 80208 USA  
ptodd@pstar.psy.du.edu

*The Adapted Mind: Evolutionary Psychology and the Generation of Culture.* Edited by Jerome H. Barkow, Leda Cosmides, and John Tooby. New York: Oxford University Press (1992). ISBN 0-19-506023-7, xii + 666 pp., \$55 hardback.

## Introduction

Psychologists have long paid lip service to Darwin, conceding that the human brain did arise through the course of evolution (for whatever, often unspecified, reason). But the full power of Darwinian theory is almost never used in day-to-day psychology research. This is peculiar, given the successful, integrated nature of evolutionary biology, and the typically fragmented and incomplete visage of modern psychology: one would think that a theory that explains the origin and maintenance of complex behavioral adaptations across all species (evolution) could inform and unify the study of human behavior (psychology) just as productively as it does the study of animal behavior (ethology and comparative cognition). But the emergence of a genuinely evolutionary psychology of humans (HEP) has been a slow, painful, and quite recent occurrence, marked at last by the publication of a flagship volume, *The Adapted Mind*. This work is of great importance not only for researchers in all branches of human psychology, but also for those in the field of adaptive behavior as well, because it demonstrates that the operation of even the most sophisticated and seemingly general behavioral system we know of -- the human brain -- can only be understood as the conglomeration of a great variety of specific mental mechanisms, each finely tuned to a particular adaptive problem. Thus, the bottom-up, modular, often evolutionary approach our field generally takes to the simulation of adaptive behavior (SAB), is just the approach most closely aligned with the modular, adapted, domain-specific nature of intelligence all the way up to the human level. As a result, the new HEP provides support for the belief that SAB research is likely to be the most promising approach to the creation of intelligent adaptive behavior at any level of sophistication.

## Some history

Psychology has not always lacked a unified theoretical foundation. Before Watson's Behaviorism divorced experimental psychology from the rest of behavioral biology early this century, Darwinian psychologists such as James Mark Baldwin, William James, George McDougall, Conway Lloyd Morgan, George Romanes, Herbert Spencer, and indeed Darwin himself, took evolution as the theoretical framework for analyzing and explaining human and animal behavior (see Richards, 1987). But the Behaviorists (as other schools of psychology that followed) turned to physics as a paragon of scientific method and mechanistic reductionism, abandoning psychology's natural affinity with comparative biology as a framework for scientific theory and functionalist analysis. As a consequence, Behaviorism rejected Darwinian theory along with introspective research methods and mentalistic concepts, in an attempt to make psychology a positivistic and independent science.

When mentalistic concepts were revived with the cognitive psychology revolution of the 1950s and 1960s, Darwinian theory remained marginalized. This was a particularly peculiar development, because the actual overthrow of Behaviorism was instigated by Chomsky's nativist psycholinguistics (see Pinker, 1994), and by the investigation of innate, domain-specific constraints on learning by Garcia and Koelling and many others (see Bolles & Beecher, 1988). But for the next couple of decades, the metaphor of "mind as computer" seemed more promising than the reality of "mind as evolved biological organ". Psychologists persisted in studying the proximate mechanisms underlying human behavior without considering their ultimate adaptive functions.

During the 1970s and 1980s, several developments laid the groundwork for a new evolutionary psychology. New developments in evolutionary theory, from Hamilton's inclusive fitness ideas to Wilson's conception of sociobiology, paved the way for a much more powerful science of animal behavior, as well as a more sophisticated and balanced understanding of human evolution (e.g. Foley, 1987). Field studies of non-human primates revealed surprising homologies to human behavior and quite sophisticated social and cognitive capacities (e.g. Byrne & Whiten, 1988). Studies of human cognitive development revealed that infants developed domain-specific competencies (e.g. face recognition, intuitive physics, social referencing) much earlier and more spontaneously than standard learning theory could account for (see Hirschfeld & Gelman, 1994). Artificial intelligence research revealed that real perception and motor control are much more difficult than previously suspected, especially in comparison to abstract reasoning and problem-solving. Furthermore, almost every computer-simulated (and biological) cognitive process suffers from problems of combinatorial explosion and the "frame problem", unless guided by "innate" domain-specific knowledge and constraints on learning. Finally, in the late 1980s, Leda Cosmides and John Tooby suggested that a new field of "evolutionary psychology" could combine the evolutionary framework of sociobiology with the psychological sophistication of cognitive science (Cosmides & Tooby, 1987). They outlined a theoretically sophisticated and empirically productive method of analyzing human mental capacities as complex biological adaptations, sculpted over evolutionary time through natural and sexual selection. The field has been burgeoning ever since.

Evolutionary psychologists, clustered at institutions like the University of Michigan and the University of California at Santa Barbara, tend to be renegades from mainstream psychology, physical anthropology, primatology, and behavioral ecology and biology. Work in this field is

often published in the journals Behavioral and Brain Sciences, Ethology and Sociobiology, and Human Nature, and the Human Behavior and Evolution Society (HBES) has yearly meetings of high quality and energy (contact Patrick McKim at pmckim@oobe.aix.calpoly.edu for membership information and pointers to the HBES electronic mailing list). Evolutionary psychology is in a difficult position because some biologists and psychologists find it politically correct or convenient to downplay the relevance of evolutionary theory for human behavior, and because some popular science writers, feminists, social scientists, and humanists seem to delight in attacking Darwinism wherever they find it. Nevertheless, evolutionary psychology is attracting support because it is the only branch of psychology that allows the study of human behavior to be conceptually integrated into the rest of natural science.

### Themes in evolutionary psychology

Biologists expect a functional mesh between the adaptive problems posed by a particular environment and the design features of particular species of organisms. Evolutionary psychology posits that humans are no exception: far from having evolved a mythical general-purpose intelligence that transcends all such specializations, we simply have a different set of species-specific mental adaptations evolved to deal with the problems that were posed by our ancestral environment. The key strategy in evolutionary psychology, then, is to analyze human mental adaptations based on their adaptive functions under our ancestral conditions. Since the most recent ancestral environment that could have shaped complex biological adaptations in humans was the Pleistocene savanna habitat of Africa, evolutionary psychologists think more about the lifestyles of hunter-gatherers 100,000 years ago, than about the lifestyles of modern humans. Human babies are born "expecting" to grow up as hunter-gatherers living in migratory tribes with complex social systems, intense parental and kinship bonds, and fluid sexual relations. Thus, our perceptual, cognitive, emotional, motivational, and behavioral adaptations are attuned to that ancestral environment, not to modern conditions. By analyzing the problems of survival and reproduction that faced our ancestors, and the perceptual cues and behavioral options available under ancestral conditions, evolutionary psychologists seek insight into the structure of the psychological adaptations or "Darwinian algorithms" that evolved to solve those problems.

Mental adaptations are not "constraints" on human behavior, that place limits on an otherwise rational, general-purpose intelligence; no such intelligence is possible, even in principle (see Tooby and Cosmides's first chapter). Rather, domain-specific mental adaptations are ENABLERS of behavior that allow competencies and actions that would not otherwise be possible. This "bottom-up" view of how evolution constructs minds and behaviors will be familiar to SAB researchers. As William James and William McDougall argued long ago, humans are unique not because we have somehow been freed from our instincts, but because we have evolved MORE instincts (mental adaptations) than other animals, allowing a greater diversity and flexibility of behavior. Recognizing the importance of these instincts need not lead to a pessimism about human potential: as Tooby and Cosmides point out, "The human psychological system is immensely flexible as to outcome: Everything that every individual has ever done in all of human history and prehistory establishes the minimum boundary of the possible. The maximum, if any, is completely unknown." (p. 40).

The physical and biological sciences take for granted a COMPATIBILITY principle: chemistry must be consistent with physics, even if chemistry cannot (yet?) be derived from physics. Mutual compatibility between sciences leads to conceptual integration. Darwin's central importance in the history of science lies in his extension of the compatibility requirement to the biological and psychological realms: evolutionary theory provides the explanatory bridge between physical simplicity and functional organic and behavioral complexity. Psychology has tried, and failed, to develop an autonomous "physics of the mind", based on general laws of learning and of cognitive processing -- laws that are completely uninformed by the principles of selection and adaptation that apply to other physical and behavioral adaptations in other species. Evolutionary psychology, if successful, will simply become psychology proper -- a field that is conceptually integrated with the rest of science, rather than a field seeking a wrong-headed independence.

### The book itself

The Adapted Mind comprises 18 chapters from 25 of the best researchers in the field, yielding a commanding 666 pages of text. Startlingly under-promoted by Oxford University Press, the volume has been reviewed infrequently and marketed sporadically, but deserves much wider attention. Jerry Barkow, Leda Cosmides, and John Tooby performed outstanding feats as editors, actively shaping the diverse contributions so they display a rare unity of vision and purpose, and a high standard of clarity and quality.

References follow each chapter, and comprehensive author and subject indexes close the book. The volume's fascination can best be illustrated by a quick skim through the subject index, which contains a tantalizing diversity of entries such as: adultery, baboons, chastity belts, color vision, ego defenses, environmental signals (clouds, flowers, water), food sharing, gossip, harems, homicide, incest, jealousy (morbid), !Kung San, learnability theory, mate-guarding, nepotism, prisoner's dilemma, rough-and-tumble play, sperm competition, tolerated scrounging, urban design applications of evolutionary aesthetics, and vomiting. This wealth of topics drives home a key insight of HEP: that human mental capacities are largely domain-specific adaptations specialized for dealing with particular kinds of perceptual cues, conceptual contents, and behavioral responses. There is no short-cut to understand the Mind in general; one must work through each of its constituent adaptations for solving particular kinds of information-processing tasks, as the authors in The Adapted Mind set themselves to do.

This functional specialization principle is widely accepted by physiologists for bodily organs and by psychologists for sensory and motor systems (see Fodor, 1983). HEP simply pushes the principle to its logical limit, to include the "central processing" underlying cognition, motivation, and emotion in higher animals. Thus, the book will strike traditional psychologists as having an unusual structure: there are no chapters on perception in general, or memory in general, or decision-making in general, or action in general. Each mental adaptation for a particular content domain is assumed to include perceptual, conceptual, reasoning, decision-making, learning, memory, and motor control subsystems. In this respect the HEP model of mind resembles Brooks's subsumption architecture for autonomous robot behavior, with independent layers or modules guiding each sort of behavior in parallel, interacting only as necessary to avoid behavioral conflict.

## Individual chapters

The individual chapters in *The Adapted Mind* bear varying degrees of applicability for researchers trying to study or create adaptive behavior in robots or simulated agents. Tooby and Cosmides's first chapter lays out the arguments for the necessary conceptual integration of the social and behavioral sciences with the natural sciences, through the medium of evolutionary theory; researchers in the adaptive behavior field should also be sensitive to this call for integration with biology in particular, since much of our work to date has been criticized for a lack of familiarity with the data from the "real" behaving systems we hope to emulate and understand. (This does not mean that simulations of adaptive behavior must model specific species or neural systems -- more abstract models, informed by knowledge of biology and the logic of evolution, can be used to develop useful generalizations ACROSS species.) They view (human) mental mechanisms as the generators and filters that create and shape the sea of culture we are immersed in, in strict accordance with the evolved information processing abilities and behavioral predilections of those mechanisms. Such a view would be a useful starting point for anyone simulating the evolution of language, culture, or memetic systems.

The second section of the book focuses on the mental mechanisms that have evolved in humans and other primates to deal with the adaptive problems of exchanging resources between individuals. Such social exchange algorithms will be of use in any system where individuals can choose to act so as to benefit another individual, from simple simulations where individuals play the iterated prisoner's dilemma against each other (Axelrod, 1987), to interacting robots that must cooperate to accomplish a goal (McFarland, 1994). As Cosmides and Tooby discuss, social exchange mechanisms must incorporate a variety of design features, including the ability to judge the costs and benefits of each act of exchange, a means of recognizing other individuals with which exchanges have taken place, and a way to tell if other individuals are cheating -- that is, accepting a benefit without subsequently offering a benefit in return. Cheaters must be detected and punished (or at least shunned), no less for robots cooperating to clean up a shop floor than for hominids sharing meat after a successful hunt. (Simulations of simpler social systems may be able to show that some other behavioral mechanisms for social exchange could also evolve and prove adaptive, which would be an exciting discovery.)

The psychology of choosing mates and holding onto them is discussed in the chapters in the third section. Since the name of the game in evolution is reproduction, there are very important and influential evolved mental mechanisms for ensuring that reproductive effort will not be wasted. Mates must be chosen to maximize the number of viable offspring that are produced, and once chosen, should be induced to continue to work toward that reproductive goal, rather than heading off to reproduce with someone else. While reproduction is certainly important in evolutionary simulations, relatively little work has been done in the adaptive behavior field on the issues of mate choice or retention (see Collins & Jefferson, 1992, and Todd & Miller, 1993, for exceptions); and in the case of physical robots, the difficulties of implementing "robot sex" have rendered reproductive matters pointless.

But the issues covered in this section can be related to any situation in which agents must choose others to cooperate with toward some fitness-increasing goal. This is true whether fitness is

defined in terms of direct production of simulated offspring, or indirect assessment of "design success" (including end-user aesthetic and biophilic appeal and other aspects of the robot's economic niche) and an eventual increase in the number of robots built back at the factory with that design. For instance, if one type of agent puts more time and energy into a cooperative task than another type of agent does (as females do in mammalian and avian reproduction), then they will be a limiting resource that the second agent type will compete for access to and control over (as males do -- see Wilson and Daly's chapter). These kinds of behavior will require the presence of information processing mechanisms for assessing time/energy investment and allowing competition within the agent types and cooperation between them. Furthermore, such choice behaviors can induce sexual selection and other effects on the course of evolution itself.

In humans and many other species, reproduction is not simply a matter of making babies, but also of raising and nurturing those offspring at least until they too are reproductively capable. Significant parental investment is necessary to ensure the survival of human infants to reproductive age, guided by significant evolved mental mechanisms, as the fourth section on parental care makes clear. Some of these behavioral adaptations are peculiar to mammalian biology (e.g., Profet's chapter on pregnancy sickness as a means of reducing the exposure of the developing embryo to toxins ingested by the mother) or to human birth patterns (e.g., Mann's chapter on maternal preference for healthier preterm twins). But others are more generally applicable to any situation where one agent has an interest in fostering the development of another (e.g., an experienced robot teaching a new robot the best way to navigate through an office environment, to save human controllers from having to do so).

Fernald, for instance, describes the peculiar features of "motherese" or infant-directed speech that are specially designed to enhance mother-infant communication: higher pitch for greater salience to the infant's developing auditory system; exaggerated and continuous pitch contours to enhance voice tracking; and highly redundant, small-repertoire vocalizations for increased signal detection. These design features not only initiate the communication of emotional and motivational states between parent and child, but also can serve to help demarcate the symbolically important linguistic elements of speech, focusing attention on individual words and thereby aiding in further language learning. Consideration of design features such as these (including setting up situations where teaching and learning can co-evolve) will be important for enhancing communication to robots or animats whose behaviors and "brains" are still developing, and for leading them to more effective learning by highlighting the aspects of the environment that should be internalized first.

Boulton and Smith consider a developmental process that typically happens independently of adults: rough-and-tumble play. This kind of activity, it is hypothesized, may help children (and young animals) to learn locomotor skills that will be necessary in adulthood, for fighting, hunting, or predator avoidance. Some form of "play" behavior may also be very useful to give more or less fragile robots the opportunity to practice and fine-tune motor control programs that may be crucial to later survival (e.g. escaping predators or other destructive forces -- see Miller & Cliff, 1994) in an initially benign and "playful" setting, removed from the consequences of making costly mistakes (e.g. being crushed by an overly-curious child).

The fifth section, on language and perception, begins with Pinker and Bloom's carefully reasoned and convincing argument (reprinted from *Behavioral and Brain Sciences*) for the evolution of

human language by natural selection, rather than as a "spandrel" or non-functional quirk. They discuss the design features and adaptive advantages of language, and provide criticism of the anti-adaptationist camp that will be valuable for anyone making selection-based explanations of evolved behavioral systems. And their paper will be inspirational in reminding SAB researchers that communication systems based on arbitrary symbolic representation and complex grammars CAN evolve (rather than just appear), even if current simulations are still far from this goal.

Shepard presents a theory for the human perception of color along three independent dimensions, stating that this design is used to achieve the important adaptive function of color constancy -- keeping objects identifiable by their color across widely-varying illumination conditions (bright sun, cloudy days, moonlight, etc.). Shepard holds that this aspect of the visual system, in common with other perceptual and cognitive abilities like the representation of motion of objects in space, is strongly attuned to structure in the world. In particular, he proposes that those characteristics of the world that have been present over the greatest amount of evolutionary time (e.g., light coming from the sun, and space being three dimensional), will be most deeply internalized. While this proposal for human color perception has yet to be proven (it is problematic that some primates have only two types of color-sensitive cones, and thus perhaps a different color perception dimensionality), the general results from Shepard's research program remain applicable to the design of the "deep" underlying perceptual and cognitive abilities of any agents inhabiting our physical world. Shepard's work also presents strong arguments for the use of internal representations in cognition, and so should be read by anyone pondering intelligence without representation (see e.g. Shepard, 1987).

Finally in this section, Silverman and Eals describe their experiments showing the existence of different mechanisms for spatial cognition, suggested by an analysis of the different spatial adaptive problems that would have faced male hunters of mobile prey and female gatherers of stationary plants in Pleistocene Africa. Their work points up the importance once again of carefully analyzing the adaptive problems faced by a behaving agent, and then considering the task-specific, rather than domain-general, solutions that can address those problems.

The two chapters in section 6, on environment aesthetics, describe how humans gain information about their surroundings, and use that information to make judgments between alternative environments. Orians and Heerwagen break the problem of habitat selection into three stages: an initial rapid decision whether or not to explore a newly-encountered landscape; a longer period of exploration of possibly suitable landscapes; and a final decision to stay in a region for some length of time or to move on in search of greener pastures (or savannas, in keeping with our Pleistocene origins). Cognition at each of these stages is sensitive to cues in the environment reflecting information about varying time-spans. These include transitory changes in weather, longer-term seasonal shifts, and nearly-permanent geographical features. Kaplan describes responses to environments in terms of the prospects for new information they afford to knowledge-seeking individuals: environments where exploration seems possible and productive are more highly valued than those where it seems easy to get lost, or where endless, featureless expanses preclude discovering anything new. Both sets of authors emphasize that the rapid, affect-laden nature of human aesthetic responses to different environments indicates the important adaptive functions of these responses. Making quick decisions about where to seek refuge or where to head to look for prey could be very advantageous in the shifting savanna. Furthermore, imbuing the reactions to

landscapes with strong emotional feelings helps to organize thought and action for the appropriate responses (fleeing, exploring, settling, etc.). The results of these research programs could be useful in building exploratory behavior, environment navigation, or "nesting site" choice into agents and robots, and the ideas about the role of affect in cognition and judgment are important for the design and understanding of any motivational system.

The penultimate chapter in the book, by Nesse and Lloyd, is about the evolution of psychodynamic mechanisms including repression, neurosis, transference, and guilt -- the types of processes focused on by psychoanalysis. This would seem a topic of singularly little interest to researchers in the SAB field (at least while at work). But in fact, the emphasis here is on intrapsychic conflict, how differences of motivation and decision between different cognitive modules within one individual can be resolved. As such, this topic is very germane to action selection algorithms and interacting motivational systems. One of the prime means of alleviating conflicting opinions between modules is to repress the outputs of one of the modules -- that is, to deceive oneself about one's own cognitions. Here, perceiving one's own internal states veridically is not necessarily the most adaptive course of behavior, just as perceiving the external world veridically is not always adaptive, either: in both cases, what is important is to process the relevant fitness affordances -- the fitness-affecting cues in the internal or external environment -- even if they contradict or mask the objective "facts" (like the actual output of an internal motivational module). Such self-deception may be particularly adaptive when trying to deceive others; if one's underlying motivations are hidden even from one's own conscious awareness, they will be that much more difficult for other competing individuals to detect and exploit. While simulations of interacting agents are certainly not yet at the level of sophistication where self-deception (or even deception of others?) is called for, these ideas should be kept in mind for the future.

### How HEP can inform SAB

The research program of evolutionary psychology helps to elucidate the adaptive problems and information-processing solutions, such as cheater-detection (chapter 3), that emerged over the course of human evolution. Researchers in SAB can use these ongoing new results from HEP most directly in two ways. As designers of new adaptively-behaving systems, we can incorporate the functions and behavioral mechanisms uncovered by evolutionary psychology into our robots or animats; and alternatively, as shepherds of simulated evolutionary design processes, we can use the results of evolutionary psychology to help us look for and understand the adaptive information-processing components in our evolved neural network or genetic programming systems. In both cases, it is important to remember that the mechanisms involved need not be as complex as those found in the brains of humans (or other living organisms) -- for instance, animats looking for cheating social partners need not incorporate things like voice stress analysis or checking for shifty eyes, but rather can rely on the simpler cues and fitness affordances present in their simplified worlds. Thus, the ultimate adaptive functions of behaviors will map from the human (or animal) to the animat (or robot) case, even if the proximate mechanisms do not.

The new evolutionary psychology view of mental origins and functions puts the simulation of adaptive behavior field on much firmer ground, and in a much more important position. SAB researchers often confront the objection that, though the behavior of simple animals can be



modeled as the outcome of domain-specific mechanisms adapted to particular environmental problems, surely there will be a need for more domain-general reasoning and learning capacities as we climb the ladder of complexity from artificial life to artificial intelligence. Familiarity with human HEP gives us a powerful defense against this objection, and a strong justification for viewing mental evolution as "adaptations all the way up". Tearing down the scientifically unjustifiable (but politically convenient) wall between human and animal cognition gives the SAB field more relevance to human psychology than even its most ardent supporters might have suspected. Additionally, in highlighting the continuity between animal and human behavior, knowing about human evolutionary psychology may also help SAB researchers on a more personal level, by making SAB work more clearly relevant to human issues, and helping us better understand the real human organisms we work with.

### How SAB can inform HEP

Cognitive psychology has dominated human psychology for the last twenty years, and the computer metaphor has always dominated cognitive psychology. Because of this, some evolutionary psychologists have found it tactically useful to adopt cognitivist and computational language in discussing mental adaptations, to make Darwinian theory more comprehensible and palatable to mainstream cognitive psychology. Indeed, Cosmides and Tooby often refer to mental adaptations as "Darwinian algorithms" that take in specific perceptual cues, transform them into internal representations of environmental situations, process those representations according to domain-specific inference rules, and output certain motor patterns in consequence. This cognitivism can be off-putting to SAB researchers who are skeptical of the entire cognitive science tradition, and who prefer to think of mental and behavioral adaptations using other models, such as dynamical systems theory (see e.g. Port & Van Gelder, in press), neural network theory, or classifier systems. It would be unfortunate if HEP became conflated with a particular cognitivist metaphor for how mental adaptations operate, because HEP can easily work with other metaphors more palatable to the SAB community. For example, Miller and Freyd (1993) have outlined how evolutionary psychology, dynamical systems models of cognition, and a broad notion of internal representation are mutually compatible. SAB research can help guide HEP by supplying a broader palette of metaphors for cognition, making HEP more adaptive in the face of changes in computational fashion in the ranks of old-fashioned psychology.

### Conclusion: Towards a universal science of behavioral evolution

Evolutionary psychology as developed in *The Adapted Mind* offers a theoretical framework and experimental methodology for studying the evolutionary origins, adaptive functions, and proximate mechanisms of human behavior. Research on the simulation of adaptive behavior as developed in this journal offers computational methods for studying the evolution, functions, and mechanisms of intelligent behavior in general. Thus, HEP and SAB work share a congruence of theoretical interests and a complementarity of empirical methods.

However, there remains a large gap between the kinds of behaviors modeled in SAB and the kinds of behaviors investigated by HEP. This gap will probably take generations to close, but until then,

it is important for each field to respect and learn from the other. Human evolutionary psychology offers a vision of the human mind that is radically different from the domain-general cognitive engine postulated by traditional psychology, or the culturally-constructed semiotic network conjectured in contemporary social science and the humanities, or the black box full of individualistic beliefs and desires assumed by the crypto-creationist portions of the public. To the extent that SAB researchers have tacitly absorbed one of these latter three models from our current largely anti-Darwinian culture, and to the extent that these models bias our understanding of what constitutes complex adaptive behavior, we will aim in exactly the wrong direction in our research. Reading *The Adapted Mind* will be a useful prophylactic against our field repeating the mistakes that psychology has been making for the last 100 years, and will provide inspiration to help forge the unified science of the evolution of adaptive behavior during the coming century.

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