Trends in Cognitive Sciences

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Opinion

In praise of folly: flexible goals and human cognition

Junyi Chu[1,2,*] Joshua B. Tenenbaum,[1] and Laura E. Schulz[1]

Humans often pursue idiosyncratic goals that appear remote from functional ends, including information gain. We suggest that this is valuable because goals (even prima facie foolish or unachievable ones) contain structured information that scaffolds thinking and planning. By evaluating hypotheses and plans with respect to their goals, humans can discover new ideas that go beyond prior knowledge and observable evidence. These hypotheses and plans can be transmitted independently of their original motivations, adapted across generations, and serve as an engine of cultural evolution. Here, we review recent empirical and computational research underlying goal generation and planning and discuss the ways that the flexibility of our motivational system supports cognitive gains for both individuals and societies.

Highlights

Beginning with play in early childhood and extending through adulthood, humans invent novel problems and pursue idiosyncratic, imaginary, and impractical goals.

This suggests that humans have a remarkably flexible capacity for accruing intrinsic reward, which can sustain thinking and planning even when objectively measurable rewards (e.g., derived from achieving goals or acting in the world) are sparse.

Goals provide essential structure for hypothesis generation and planning. Given that the ideas generated in pursuit of idiosyncratic ends can be decoupled from their original motivations, transmitted across cultures and generations, and adapted and repurposed, goals scaffold the generation of new ideas.

We review research on decision-making, play, and motivation, and consider how goals, even frivolous ones, can lead to valuable outcomes for individuals and society as a whole.

A puzzle of goal-directed behavior

Many cognitive scientists are interested in how humans can learn so much from so little so quickly [1–3]; others focus on the relatively slow process of conceptual change, and the ways that human judgments are slow, biased, and fallible [4–6]. Recent work has bridged these accounts, considering how we might act rationally given limited cognitive resources [7,8]. However, none of these approaches explain humans' predilection for thinking about things that are, so to speak, neither wrong nor right: things that are imaginary, or if real, of no apparent practical value. We pursue not only goals that have at best a tenuous connection to survival or reproductive success (e.g., digging up dinosaur bones or lining up dominoes to knock them down), but also goals seemingly in direct conflict with those ends (e.g., skydiving or chastity). Humans are not of course immune from evolutionary pressures, but this suggests that a remarkable degree of latitude in human desires is compatible with, and possibly helpful to, human survival.

Why do humans engage with goals that appear prima facie unlikely to pay off in the near term with respect to achievement or learning? We suggest that goals provide constraints that support the generation of plans and ideas, and that pursuing apparently frivolous ends enables a rich variation and proliferation of human thought (Figure 1). We begin by laying out what we mean by a goal and then focus on four features of human goals: their flexibility, productivity, value, and cultural transmission and adaptation.

What is a goal and what kinds of goals are we interested in?

Goals, rational action, and mental states

Evolution has equipped all organisms with ways to achieve ends useful to their survival. Insofar as any adaptive behavior is goal oriented, we might say that sunflowers have the goal of moving toward sunlight and their roots the goal of moving away from it. However, such ends are fixed: sunflowers cannot turn away from the sun if it gets too hot, and roots cannot seek daylight if it gets too cold. By contrast, intelligent agents can use internal models of the world and its

[1]Massachusetts Institute of Technology, Cambridge, MA, USA
[2]Harvard University, Cambridge, MA, USA

*Correspondence: junyichu@mit.edu (J. Chu).

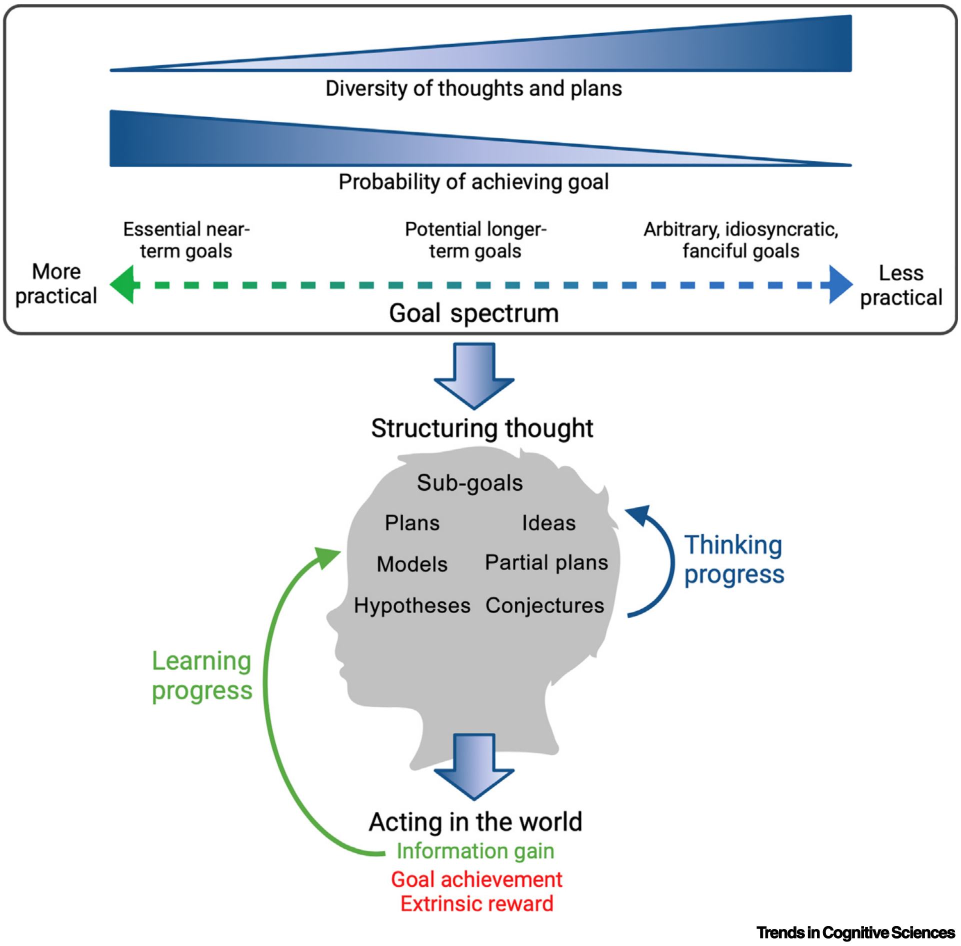

Figure 1. Practical and impractical goals with different implications for action, learning, and thinking. All goals, practical or fanciful, constrain the hypothesis space and support the generation of new ideas, plans, and other cognitive structures. However, the variability of thoughts generated in pursuit of practical goals will necessarily be more limited than the range supported by all possible human goals (gradient toward darker shades indicating increased probability). By the same token, arbitrary and idiosyncratic goals are inherently less achievable. Thus, practical goals are more likely to translate into actions, which in turn have some probability of leading to real-world outcomes (and extrinsic rewards) or gains in information or skills that lead to learning progress (green arrow). Frivolous or fanciful goals will be less likely to translate into actions, achievement, or learning, but are more likely to generate richly novel cognitive structures: thinking progress (blue arrow). Given that plans can be decoupled from the goals that inspired them and because humans transmit ideas intergenerationally, even once frivolous goals may lead to a broad range of valuable outcomes. Figure created using BioRender (biorender.com).

dynamics to evaluate the likely consequences of their actions and choose to act when the expected reward of acting outweighs the expected costs. In this sense, the goal of all rational agents is always to achieve high expected utility, and the particulars of the utility functions of agents represent the specific goals they are inclined to pursue.

Here, however, our focus is on a richer sense of goal-directed behavior in which goals are mental states, that is, intentions to achieve outcomes. Goals in this sense are causal: they organize and guide the behavior of agents via planning. They are also hierarchically structured in nested systems of subgoals. Of course, even animals capable of abstract mental state goals (for a recent account of the phylogeny of agency, see [9]) have explicit access only to some levels of this hierarchy (e.g., we may be aware of the goal of picking up a pen but not the detailed subgoals in the motor plan). Here, we focus on goals to which agents have conscious access and their distinctive role in human thinking and planning.

Distinguishing goal-directed action in humans and other animals

As with all mental state inferences, outwardly observable behavior underdetermines the underlying mental states. We can twirl a pen unconsciously, as a nervous habit, or intentionally, trying to open the cap. Nonetheless, we can often distinguish goal-directed behavior from other behavior empirically. Goal-directed behavior is both efficient with respect to the goal (maximizing the probability of achieving the goal relative to the cost of action) and equifinal: a goal-directed agent will seek other means to pursue their end if the original path is blocked [10–12]. To borrow an example from William James: iron filings and Romeo may both move directly toward their targets, but the iron filings will be stopped by a barrier; Romeo will find a way around it.

A range of computational approaches in artificial intelligence (AI), machine learning, and cognitive science have attempted to characterize many kinds of goal-directed behavior in rational and functional terms (Box 1). These efforts have inspired and informed our work here, but they have not yet confronted the most puzzling features of human goals we seek to explain. Human goals lie on a continuum with those of other animals (Box 2). Yet, they also have several characteristics that we believe not only result from, but also contribute to, the distinctive sophistication and successes of

Box 1. Computational formalisms for goal-directed behavior

Formal models of goal-directed behavior offer multiple routes to choosing actions that maximize expected long-run future utility. Reinforcement learning (RL) has a long history in both neuroscience and AI. Model-free RL agents are simple but inflexible: they use trial and error to learn fixed policies (mappings from states to actions) that maximize value (or long-run expected reward). Model-based agents are more flexible: they use models of the environment (e.g., a spatial map, or a more abstract representation of how actions probabilistically affect state transitions, rewards, and costs) to compute on the fly, through a process of planning, action sequences with high expected value, and they can replan online, adaptively, if their world model or goals (utilities) change.

Both model-free and model-based RL approaches have generated insights into how the brain computes reward in simple decision-making tasks [86,87], and hybrid approaches have been especially influential [7]. However, these classic RL methods may fail in the complex worlds that humans occupy and construct, where external rewards are often sparse, unpredictable, and only accessible after long action sequences [25]. More cognitively inspired recent work aims to build utility-seeking agents that come closer to human planning and learning capacities.

Hierarchical planning can help achieve long-range objectives by constructing hierarchies of subgoals [88,89]; these could include partial completion of the final goal, acquiring some means to an end, or purely epistemic goals (e.g., learning where a tool is located, or learning about one's own ability to accomplish a task). Such subgoals may be the source of intrinsic rewards that rationally signal 'action progress' or 'learning progress' to the agent [90,91], and that could be the locus of positive evolutionary pressures [92]. Especially relevant to our focus here are autotelic RL methods [74,93], which explicitly pursue self-generated goals to expose agents to new experiences they would not otherwise encounter and enable them to learn what would be hard to learn with more traditional RL approaches. Generating goals completely at random (or 'goal babbling' [94,95]) can be surprisingly powerful, even when those goals are not achieved: for instance, the mechanism of 'hindsight goal relabeling' can identify action sequences that reach any novel state (not necessarily the original goal) as successful means to that end. Plan components or planning operators discovered in pursuit of these arbitrary goals can then be reused to achieve other externally rewarded goals, potentially leading to open-ended learning and innovation.

However, the rational foundation of all these frameworks becomes problematic for some of the most motivating human goals. The ultimate prospects of external payoff may be so remote, with such low probability of success or such high uncertainty about its value, that no intrinsic rewards for achieving subgoals or learning progress provide reliable signals (see 'Flexibility: long-term goals' in the main text). Moreover, humans appear to find value in constructing and thinking about models of the world that they believe to be false or know will never be true, planning toward goals that could not be accomplished and where any specific plan components or operators produced have no direct potential for reuse in the real world. To our knowledge, no rational computational approaches have attempted to account for this kind of goal-directed cognition.

Box 2. Goals in humans and other animals

At its simplest, all organisms capable of classical or operant learning can assign value to an otherwise neutral state or action that is paired frequently or powerfully enough with a species-specific reinforcer; the animal then learns to approach or avoid the arbitrary cue. However, many animals are also capable of more sophisticated forms of learning and decision-making, involving multistep sequences [96,97]. Models of RL (Box 1) have characterized ways in which reward can be propagated backward from end goals to subgoals, such that actions and states with no inherent value in themselves become valuable as steps toward desirable outcomes.

Beyond responding to reinforcers in their environment, nonhuman animals also act for social [98] and epistemic ends [99]. In particular, many animals will explore novel, complex, and surprising stimuli in the absence of any external payoff [100]. Recent work has added precision to these claims, distinguishing, for instance, the impact of extrinsic reward versus reducing uncertainty on the visual saccades of rhesus monkeys [101]. More broadly, computational work [48,74,102] suggests that many different kinds of proxy goals support learning new knowledge and skills, including exploring rare, novel, or surprising events [103], trying to maximize expected information gain or the rate of reducing prediction error [47,49,104], or trying to perform particular actions and reach particular states [105,106]. Thus, even beyond the dazzling array of species-specific 'hard-wired' goals (e.g., building hives or dams [107,108] or migrating north and south [109,110]), nonhuman animals pursue a range of exploratory behaviors that allow them to flexibly navigate and respond in real time to dynamic environments.

All of these kinds of goal-directed action are of course also present very early in humans. Babies visually explore objects from birth [111]; manipulate objects as soon as they can reach [112], and, by 10 months, enact simple plans to achieve rewarding goals (e.g., pulling on a blanket to get an out-of-reach toy [113]). Infants also actively pursue social rewards, smiling and cooing in response to loved ones [114], responding to others' emotional expressions [115,116], and engaging in turn-taking social interactions [117]. Finally, of course, infants engage in explicitly epistemic behaviors: looking longer at rare and surprising events [118,119], exploring objects that violate their prior beliefs [120,121], and selectively attending to the object of adults' gaze and points [122]. However, while humans share many goals with other species, human goal-directed behavior is also distinctive in several respects, as discussed in the main text.

human cognition. We turn now to these characteristics and the challenges they pose for theories of cognition.

Flexibility

Most work on human cognition has emphasized the sophistication of our representational system: its capacity for recursion [13,14], compositionality [15], symbolic manipulation [16], communication [17,18], and so on. We have no doubt that capacities such as these are fundamental to the kinds of goal humans can entertain; the ability to express goals in symbolic languages of thought [19,20] and natural language and share goals with others surely expands the range of goals humans consider. However, we suggest that it is not only the relative advantages of our representational system, but also the relative independence of our motivational system that contributes to the successes of human cognition.

Long-range goals

Although many animals pursue long-term goals (e.g., migrating, or building nests or dams), such behaviors are relatively automatic and inflexible. The ability to plan toward novel future goals, even on relatively short time horizons (e.g., in selecting tools for use in a subsequent task or tokens for future bartering) has been documented only in corvids and great apes [21–23] (although see [24]). In addition, humans are unique in our ability to set flexible goals that may take months, years, or even lifetimes to achieve.

The ability to engage in long-range planning requires the ability to break a goal into subgoals. Such subgoals may be far from the final goal, but the individual must still be motivated to take the first steps. Traditional models of reinforcement learning used in the study of animal behavior struggle to account for this kind of long-range planning [25]. However, despite uncertain and unlikely payoffs, humans do make long-range plans, suggesting a remarkably flexible capacity for accruing intrinsic reward. The capacity to experience reward independent of near-term outcomes contributes to the flexibility of human motivation.

Within-species variability

Considerable attention has been paid to the ability of humans to cooperate, divide labor, and collaborate (e.g., [26]); however, we suggest that individuals' motivation to pursue differing ends is at least as fundamental to our species' success. Individual humans differ not only in temperament and abilities (like individuals of many species [27]), but also in interests: that is, the particular things we want to do. Specialized interests emerge early, and early interests are both variable and enduring. For instance, one study found that more than half of 4–6-year-olds reported an idiosyncratic interest, from bugs to ballet, and one-fifth maintained that interest over 2 years [28]. This variability of interests also manifests in adulthood [29] and across cultures [30]. Given that we invent different problems, motivated by our own unique constellation of experiences, abilities and interests, we can collectively pursue a remarkable range of goals as a species.

Making up problems for fun

Beyond individual differences in interests, humans also invent novel goals, especially in the behavior we call play. Many nonhuman animals play, and different forms of play serve a range of cognitive and noncognitive ends (Box 3). However, starting around age 3, humans are particularly likely to invent made-up problems and goals. Although researchers have suggested that the randomness and variability associated with children's play might be important to learning (e.g., [31]), neither random behavior, nor a mere preference for novel actions, supports learning in open-ended contexts where external rewards are sparse [32]. Moreover, children at play do not simply act randomly; they construct novel goals and plans ('Let's balance cups on the cat/cross the room without touching the floor/pretend to be rocks' [33]). We suggest that, in its variability, structure, and value, this kind of play shares much in common with aspects of human goal-directed behavior that continue throughout the lifespan.

Box 3. Many functions of play

Play is a rich, multifaceted phenomenon that likely serves different functions in different contexts. This article is on human goals broadly, and it is beyond our scope to provide a comprehensive review of the literature on play in humans and other animals, or across human cultures (for recent reviews, see [123–126]). Briefly however, researchers have suggested a variety of accounts to explain the value of play across species, including that it might serve to promote or signal physical fitness [78,127]; strengthen social bonds [128,129], or help agents gain information about their environment and their own competencies [130–132]. Extensive work in humans has looked specifically at the potential benefits of imaginary play [133,134], suggesting that it contributes to competencies ranging from language skills [135] and counterfactual reasoning [136], to social cognition [137] and executive function skills [138].

These accounts of play are not mutually exclusive and there is good reason to believe that each characterizes some aspects of play in humans and other animals. Thus, although we argue here that some forms of play, especially in older children and adults, may not be closely tied to immediate functional ends, other forms of play in humans and other species may indeed provide direct benefits to the individual.

Play is also a cross-cultural universal, even down to some of its particulars. Despite children's reputation for having short attention spans, their play often consumes a substantial portion of their time, ~3 h a day in the USA and Japan [139], comparable to estimates for 4–16-year-olds in two subsistence communities (each quite different from the other) in the Congo basin, the Aka and Ngandu [140]. In addition, approximately one-third of playtime in both these communities is categorized as 'pretense' or 'idiosyncratic', comparable to estimates of pretend play in kindergartens in Eastern Slovakia [141]. Indeed, imaginative play persists even in cultures, which actively discourage it, such as traditional Mennonite communities [142]. Dedicated areas for children's play across the world [143] and even in the prehistoric archeological record [144] suggest that human cultures have always found it rewarding to play, highlighting the value we place on non-utilitarian, idiosyncratic goals and thinking and planning for their own sake.

We have in mind the idiosyncratic but perfectly ordinary activities of a 6-year-old, racing through the house, who, when asked to account for their behavior, explains that they and their sloth friend are trying to put out a fire on Jupiter. This is an unlikely route to learning new information about sloths, fires, or Jupiter, and, although the child may experience rewards associated with simulating their progress toward the imagined goal, they may be as likely to thwart their own progress as advance it: reigniting the fire, or 'discovering' that the fire is enchanted and impervious to all attempts. The child can vary the problem at will, assigning costs and rewards as they like. Moreover, the child may abandon this goal (and any attendant mess) after a few hours and never look back. It is not that the child is indifferent to their goal (woe betide the grown-up who tries to interrupt a playing child), but the accomplishment of the goal, and even measurable progress toward it, does not appear essential to what the child finds rewarding.

Play is not limited to children; much of what adults find rewarding also involves engaging with problems we do not (otherwise) have. Neither is the propensity to be absorbed by arbitrary goals limited to those endeavors we call play; goals can be 'made-up' without being imaginary. A single salient example may suffice. A gentleman named Gareth Wild recently made headlines for successfully parking in all 211 parking spots at a supermarket[i]. The project took him 6 years. Although this did, remarkably, result in a moment of glory, it would hardly have been rational for him to have pursued the goal with that expectation in mind: obsessing over parking spots in a grocery store is an unlikely route to either improved social status or new knowledge and skills. Presumably the value of the goal is simply that Mr Wild assigned value to it.

Modern Western culture may take a particularly indulgent view of play, but play is a cross-cultural universal (Box 3). From childhood onward, humans are able to commit passionately to goal-directed activities while simultaneously remaining relatively indifferent to their functional consequences. Exercising our capacity for inventing and engaging with arbitrary problems is sufficiently rewarding that it is what humans, both children and adults, do for fun.

We propose that the ability to pursue goals not tied to near-term outcomes benefits cognition, because the structure of goals and problems allows us to bootstrap new plans and ideas (see section on 'Productivity'). We suggest that the intrinsic reward signals to which humans are attuned include not only progress toward a goal, or the rate of uncertainty reduction or learning progress [34], but also our degree of engagement, or rate of thinking (see section on 'Value to the Individual'). Finally, we discuss the process by which even goals originally adopted only because they were attractive in themselves may ultimately lead to outcomes of wide value for learning and achievement (see section on 'Intergenerational transmission and adaptation').

Productivity

Flexibility untethered from the imperative to accomplish particular ends might appear inherently unproductive. By contrast, we believe that the rich range of short- and long-term goals that humans set for themselves out of fun or interest are immensely productive, only not exclusively in terms of extrinsic reward, social rewards, goal achievement, or even learning for the individual. Instead, any goal, however ludicrous, unattainable, or fictitious, contains structured information that imposes valuable constraints on thinking and planning. This matters in two respects.

Conditional rationality

First, although humans willingly incur otherwise unnecessary costs for arbitrary and even unachievable rewards, they nonetheless behave rationally with respect to their goals. A child may fight an imaginary fire, but belying the surface irrationality (i.e., expending energy racing toward a nonexistent target), they will engage an efficient action plan, taking the shortest path to the supposed flames (narrowly avoiding any obstacles, visible only to them, along the way). This phenomenon was investigated experimentally in recent work [35]. Although children violate principles of rational action in play (willfully pursuing fixed rewards at unnecessary costs), they behave rationally with respect to those goals; taking the most direct route consistent with their self-imposed constraints (Figure 2A). Consistent with abundant work on the ways in which children impose real world boundaries on imaginary contexts (e.g., mopping up pretend tea in the precise location where it 'spilled' [36–38]), children's play is conditionally rational: rational with respect to the goal, problem, and constraints they have set. Thus, even arbitrary goals support thinking and planning.

Structured problem spaces and 'in-principle' solutions

Second, goals set up structured problem spaces, providing information about how to achieve them. Suppose the playing child announces that the sloth is afraid to slide down the fire pole. By many measures, this is an insoluble problem by virtue of not being a problem at all: There is no sloth and there is no pole. Nonetheless, humans are perfectly capable of generating candidate solutions (e.g., bribe the sloth with candy bars or tell the sloth it'll win bravest animal of the year award). Like the goal, such solutions are at once both nonsensical and reasonable: they satisfy the abstract constraints imposed by the goal (providing an unwilling agent with reasons

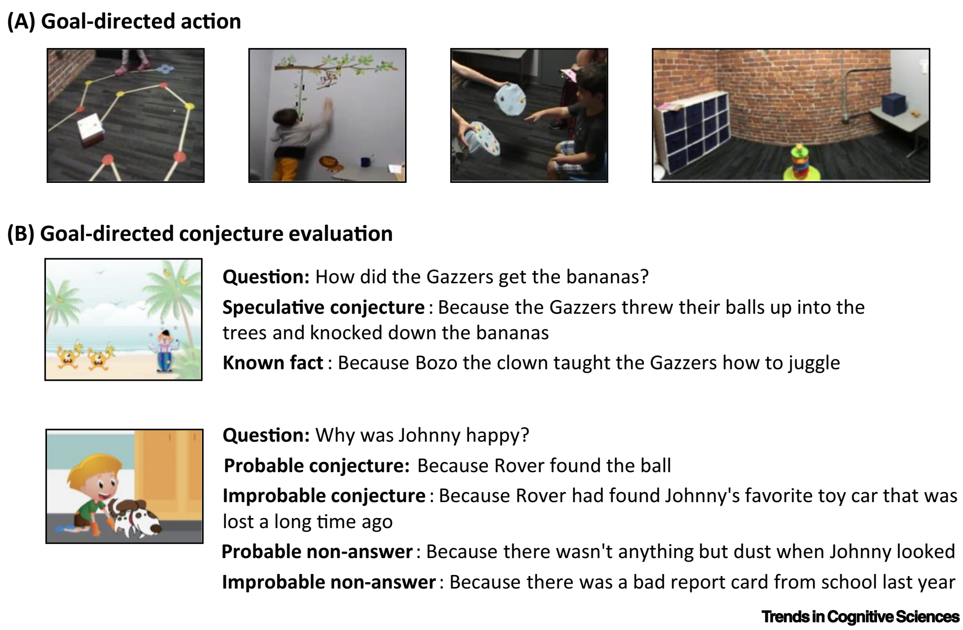

Figure 2. Arbitrary goals, conditional rationality, and in-principle solutions. We have argued that humans voluntarily incur unnecessary costs for arbitrary rewards, but that goals, even arbitrary ones, provide valuable constraints that constrain thinking and planning. (A) In two experiments [35], it was found that children chose more costly actions when told to 'Go play' and find a target than when simply asked to 'Go get' the target. Children took a spiral rather than a direct path to retrieve stickers; jumped for a pencil high on a wall; and preferentially searched for targets in larger search spaces (i.e., an eight-button over a two-button toy, a 12-drawer shelf over a one-drawer shelf). Nonetheless, children's actions were conditionally rational: they behaved efficiently (e.g., sticking close to the path, jumping directly up to the pencil, or checking adjacent locations) with respect to their self-imposed goals. (B) In two other experiments [39], participants were asked to rate answers to questions about a story. Despite a well-established preference for reliable evidence [145,146], children preferentially endorsed speculative conjectures that could achieve the goal of answering the question when known facts could not, and (similarly to adults) endorsed even highly improbable conjectures that could answer the question in principle over probable (and improbable) answers that could not. Thus, from an early age, we appear to evaluate hypotheses with respect to how well they achieve the goal of potentially answering the question, not merely with respect to the facts.

to perform an action). By contrast, many real-world facts about sloths (that they have poor eyesight and can turn their heads 270°) do not.

What is true for the child and sloth is true for humans' arbitrary goals in general. Both adults and children endorse speculative conjectures that provide 'in principle' solutions to problems, even if they have no other supporting evidence, and both adults and children prefer even improbable conjectures that satisfy problem constraints over verifiable facts that do not (Figure 2B) [39]. That is, we evaluate ideas with respect to their utility, or how well they satisfy the goal (i.e., the explanatory or other constraints imposed by the problem [40,41]), not only with respect to their probability. Thus, we can say an idea 'is a good one' not only before we have tested it, but also sometimes even when we know that it is false (e.g., as when we admire the logic behind a child's speculation that boy babies grow in fathers' bellies and girl babies in mothers').

In the sloth example, we expressed the problem and solution in language, and language indeed offers us a great deal in the way of well-structured hypothesis spaces [42]. For instance, long before we can answer a question, we know what kind of a response will count as answers ('who' questions refer to social networks; 'where' to spatial maps; 'when' questions to a timeline; 'what' to a category structure; 'which' to a Venn diagram; 'how' to a circuit; and 'why' to causal networks). However, all goals, not only linguistic queries, impose structured limits on their solutions. The goal of getting a sloth down from a fire pole imposes different constraints than the goal of getting the sloth up it. All that is essential for a goal to be productive is that it contains enough information to delimit the possibilities for a solution.

Conversely, not every grammatical statement that takes the form of a goal provides informative constraints. 'Get the imaginary sloth down the imaginary firepole' is a productive goal, whereas 'Get the imaginary sloth down all imaginary things' is not. The issue is not the degree to which either is attainable (neither is); the issue is that the first has a defined problem space with clear start and end states but the second does not [43]. Similarly, 'Make sure the (imaginary) sloth doesn't eat too many lollipops' is a productive goal but 'Explain why (real) sloths eat so many lollipops' is not. We can make plans in imaginary problem spaces; we cannot think at all if the problem space fails to exist either in reality or in our imagination. While humans may entertain any manner of questionable goals, we predict that humans rarely, if ever, engage with goals that are so ill-posed that they fail to constrain the search for solutions.

Combine the idea that goals are productive and informative for thinking and planning with our ability to set goals flexibly and the result is a process that allows ideas to flourish unchecked. The 'unchecked' part is key: nothing in this process guarantees that any given idea will be beneficial now or ever. Nonetheless, insofar as human goals are both flexible and productive, they allow us to think of plans we might never have thought of had we not been trying to solve the (potentially ridiculous and insoluble) problems we were attempting. Our ability to set up arbitrary problems, and the fact that problems provide constraints on their own solutions, may account for much of the generativity of human thought.

Value to the individual

Humans pursue goals that unfold over a lifetime or even over generations; invest energy in goals based on arbitrary or imaginary premises; and positively evaluate knowably false ideas that satisfy the abstract constraints of a query or goal. What motivates individuals to engage in these kinds of behavior?

Thinking as a net cost or reward?

Most accounts of cognition treat attention, memory, processing speed, and capacity for decision-making as limited resources. Work on resource rationality proposes that we can build more accurate models of behavior by accounting for these costs of thinking and planning [7,8]. We endorse this perspective.

However, in many contexts, thinking may still be experienced as net positive. Given the many contexts in which thinking and planning pay off directly, we may come to assign value to these cognitive activities by their frequent association with real-world gains (for related ideas on 'learned industriousness', see [44,45]). Thus, humans may find the activity of thinking and planning rewarding, just as we sometimes find it rewarding to deploy physical effort [45]. In addition, although individuals vary in how much they value cognitive activities per se [46], humans in general may value these activities more than any other species do.

Additionally, as noted, our capacity for long-range planning implies that we can assign value to states intermediary to a goal and, thus, experience reward for achieving steps on the way. Recent reinforcement learning research has suggested measures of action progress and learning progress to quantify and explain the rational basis for these sources of reward (Box 1) [47–50]. Insofar as thinking and planning are invoked in the pursuit of almost any goal, they may be intrinsically motivating for analogous reasons, tracking metrics of 'thinking progress' that monitor the construction and evaluation of new internal representations (new hypotheses, subgoals, or strategies) generated in the course of reasoning or planning. In some cases, one could construe thinking progress as a form of 'subjective learning progress', if the mental processes of constructing goals and other internal representations are taken as necessary intermediate steps toward achieving an external goal; such steps may be highly motivating, even when the ultimate goal is not in fact achieved or is impossible to achieve [51]. Thinking progress could occur independently of any objectively measurable achievement or learning progress.

The proposal that we might be attuned to the degree to which we are engaged in, and making progress on, thinking and planning is consistent with the finding that humans have metacognitive awareness from early in childhood [52]. Although we can fail to anticipate the pleasures associated with 'just thinking' [53], humans are attuned to their current state of flow or engagement [54,55] and persist in activities that sustain it (see [54–60] for related proposals). Insofar as we perceive some kinds of cognitive effort as rewarding [45], this may motivate us not only to work on problems where other payoffs are remote or unlikely, but also to make up new problems of our own. Early researchers in intrinsic motivation discussed the possibility of behavior the reward of which was the opportunity to continue engaging in it [54,60]. If problems contain structured information that supports the generation of new thoughts and plans, and if thinking and planning are themselves rewarding, then making up new problems may be a means of generating new sources of intrinsic reward. Goals (even ones with no other apparent value) may set up a virtuous cycle where the structure of the goal both enables and motivates us to think.

In these respects, our willingness to pursue costly arbitrary goals in the absence of instrumental ends bears some resemblance to epistemic curiosity (the intrinsic motivation to seek information about the world), which can be formalized as acting to maximize expected information gain [34,61–63]. Indeed, humans (and many other animals; Box 2) can be curious about information even when it is seemingly irrelevant to functional ends [64,65] and even when it is costly to accrue (e.g., when accompanied by an electric shock [66]). However, we are especially motivated to seek information when it is perceived as instrumentally useful [67,68] and easy to obtain [69,70], and information typically does help us understand the world [71]. By contrast, humans can pursue costly arbitrary goals even when doing so does not lead to information gain. Thus, we suggest that the reward of pursuing seemingly arbitrary or foolish ends is not in learning or achievement, but in thinking itself.

This does not guarantee that we will find thinking about just any problem attractive. As discussed, individuals differ in their idiosyncratic content interests. Decades of work on curiosity also suggest that learners are drawn to problems of intermediate complexity: neither too easy nor too difficult [34,72,73]. Something comparable may apply to our attraction to goals. Some goals and problems may have too little structure to scaffold thought. Others may be too complex to readily support planning and hypothesis generation. Humans may be especially attracted to problems and goals that contain sufficient information and structure to sustain thinking and planning.

Crucially, thinking progress may come not only from making measurable headway (e.g., in identifying subgoals), but also just from identifying or constructing a well-constrained problem. Given only a goal, setting up a problem to solve that we judge to be well formed or tractable, with our desired goal as the end state and a starting state that we know how to approach, with feasible moves or operators that can plausibly take us to the end state, is the first and arguably most important step in making (internally measurable) thinking progress.

How do we invent new goals in the first place? In addition to our capacity for abstraction and generalization, researchers have suggested that immersion in a scaffolded social context and the combinatorial power of language may support the generation of out-of-distribution goals (e.g., [74]). However, empirical work on generating goals in this manner has been limited to the recombination of existing propositions. Humans are far more creative. We can explore multiple possible solutions to ill-defined problems [75] and pursue novel ideas that are nonetheless adapted to the constraints of the problem at hand [76]. These capacities appear to be intimately related to our ability to adopt goals flexibly and use the structure of the goals to bootstrap novel hypotheses and plans. Still, creativity has eluded formal description [77] and the processes that underlie the richness of human innovation remain a topic for future inquiry (see Outstanding questions).

Evolutionary and cultural value

We turn now to a tension at the core of this article: we set out to ask about the value of activities the prima facie value of which is not obvious. If individuals experience intrinsic reward for thinking about things that support neither real-world learning nor useful achievement, we are arguably engaged in a cognitive Ponzi scheme. How might such abilities have emerged and how might they be sustained?

Cognitive and cultural niches

We first note that humans are most likely to pursue nonessential goals only when our more fundamental needs have been satisfied. Across species, play indicates the absence of fitness threats [78]. If humans are most likely to take on arbitrary goals only when it poses no threat to their welfare, there may be no mechanism by which such activities will be selected against.

More broadly, however, our account is consistent with at least two mechanisms proposed to account for the richness and flexibility of human minds. One proposal (the 'cognitive niche' hypothesis [79,80]) suggests that humans have specific adaptations to physical problem-solving and social coordination that enable us to reason flexibly across diverse contexts (rather than engaging in distinct, domain-specific learning adapted for a specific set of problems). Given that we engage in abstract reasoning, we can then extend these cognitive abilities toward ends that may not have direct functional payoffs, including art and music.

A related but different proposal ('the cultural niche' hypothesis [81–83]) argues that the uniquely human adaptation is not our flexible intelligence but our capacity for cultural transmission. No individual could acquire the breadth of knowledge necessary to survive in some of the most forbidding environments on Earth. However, a species that can accumulate knowledge across individuals and generations can.

Both the cognitive and cultural niche proposals suggest frameworks for the emergence of a host of abilities (language, causal reasoning, communication, etc.) relevant to the flexible pursuit of arbitrary goals. The social reward associated with cultural transmission also provides a mechanism for generating ideas that will be shared and for sharing the ideas of others. Finally, our proposal, that humans are motivated to invent problems for themselves, amplifies the value of our other cognitive abilities by offering the structure and incentive for innovation.

Intergenerational transmission and adaptation

Critically, ideas and plans can be decoupled from the goals that gave rise to them and be repurposed for other ends. Goals arguably once pursued just for fun laid the groundwork for technologies now adapted for a range of other valuable ends (Figure 3). Even foolish goals (i.e., goals widely regarded as foolish both contemporaneously and now) can pay off in unexpected ways: for instance, we owe some of the science of cryptography to misguided attempts to show that Shakespeare's plays were authored by Francis Bacon [84]. In principle, even the attempt to park in every spot at a grocery store could have led to the development of a never-before-discovered search algorithm. In this case, that failed to happen, but the potential for real discoveries from frivolous ends remains.

Our willingness to transmit goals and plans even when the goals are arbitrary or the detailed mechanisms are lost, opaque, or unknown, allows ideas to spread and adapt. Humans invest a large portion of our excess resources in the pursuit of arbitrary goals (e.g., video games are played by 3.24 billion people, or ~40% of the world's population[ii]), but we also enjoy the fruits of others' labors: we watch movies and plays, listen to stories, and attend spectator sports, and even make a spectator sport of watching others play video games. Given that we accumulate knowledge collectively and transmit it broadly [13,85], among the things we pass on are the invented problems of previous generations. Ancient China and Rome are long gone; go and Hercules endure. Our impractical goals are less likely to pay off in achievement or even in goal-directed action than are more practical ones; however, they may be as likely as practical goals to constrain the hypothesis space and support the generation of new plans and ideas (Figure 1).

The world is full of unknown unknowns. If we only took on goals we expected to achieve or where we at least expected to gain new information, we would miss the chance to learn the unexpected. Even when our goals are unrealizable or foolish, they may lead to ideas of enduring practical utility. Make no mistake: the flexibility and productivity of our goals, and the possibility of decoupling our goals from immediately useful consequences, can also lead us astray: Years can be wasted looking for fountains of youth, counting angels on pins, and pursuing far more destructive delusions. Still, the satisfaction that humans get merely from being able to keep thinking about a problem may also motivate us to work on ideas we will never see confirmed and toward ends we will never see fulfilled. Many of these ideas will be fruitless or foolish but some may change the world.

Concluding remarks

We have argued that human cognition is unique, not only for the sophistication of our representational abilities, but also for the flexibility, structure, and value of our motivational system. We willingly incur otherwise unnecessary costs to achieve arbitrary rewards consistent with goals,

Outstanding questions

What challenges does the flexibility of human goals pose for our theories of exploration, planning, and inference? How do we translate abstract goals ('rescue the sloth') into specific reward functions or satisfaction criteria that support planning and hypothesis generation? How can we leverage computational models of planning and inference to explain how humans represent, select among, and eventually achieve arbitrary goals?

How do we represent and search within the space of possible goals? Is the space of possible goals a uniform distribution over any possible desire, or might they be organized and structured, just as our beliefs may be organized around concepts and hierarchically structured in the form of intuitive theories?

What does it mean for a goal to set up a well-specified problem? How do we predict expected cognitive engagement for a novel goal? To what extent do individuals converge when evaluating a goal, and how might these judgments vary with respect to differences in individual knowledge, preferences, and abilities?

What combination of domain knowledge, individual preferences and abilities, and contingent opportunities leads us to take on the array of goals we do? Where do our idiosyncratic goals themselves come from? Do we develop expertise in creating and selecting well-posed problems? If so, is that domain specific or domain general and how is it acquired?

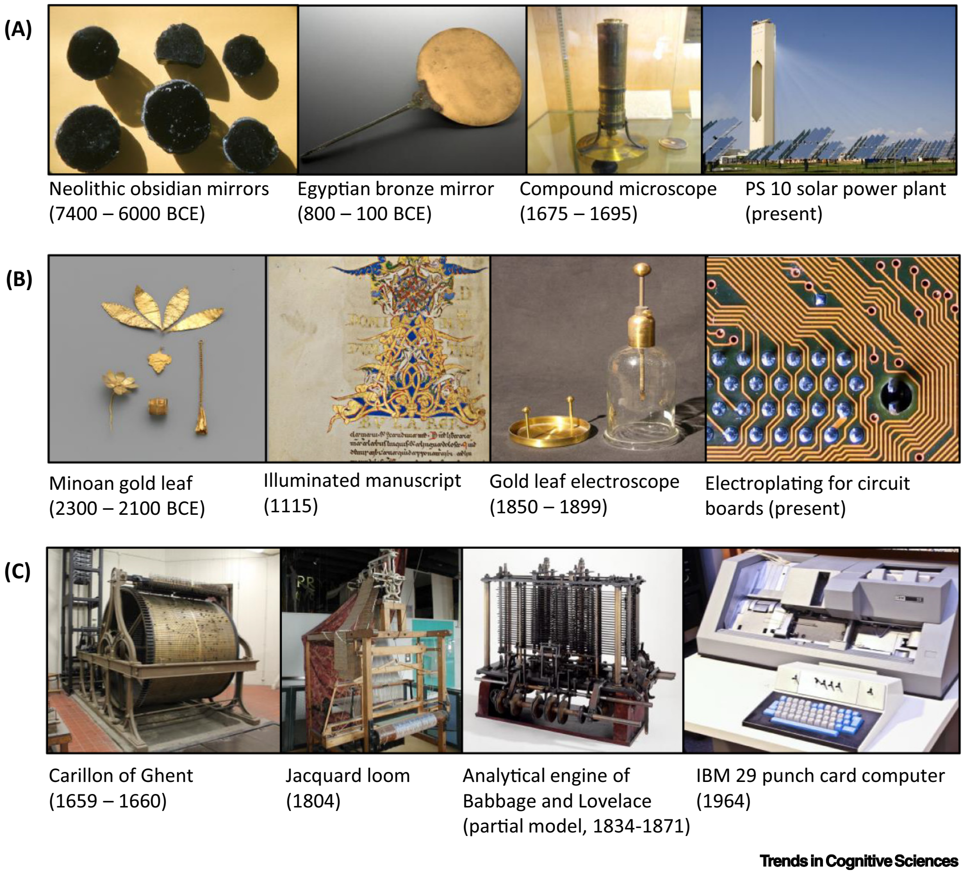

Figure 3. Goals pursued for fun can lead to instrumentally valuable innovations. Humans can assign value to ends 'for their own sake' (because we find pleasure in looking at or listening to something). It is neither obvious nor necessary that such goals might ever lead to other valuable outcomes. However, because goals can be decoupled from their original ends and adapted over generations of cultural transmission, the pursuit of frivolous ends (i.e., for entertainment or aesthetic ends) sometimes leads to innovations that permit widespread opportunities for learning and achievement. A few examples include: (A) the progression from polished obsidian to vanity mirrors to microscopes and solar panels [147]; (B) gold leaf initially used ornamentally and later adapted for electroscopes and circuit boards [148]; and (C) the progression from music boxes and carillons to the Jacquard loom to Babbage's analytical machine to early computers [149]. Even unfinished goals can structure thinking and scaffold new ideas, as exemplified by Ada Lovelace's notes [150] on the Analytical Engine, an unbuilt invention by Charles Babbage. In describing how to use the Engine, Lovelace expressed a vision for general-purpose programmable computers, years before any such machines existed. All images from Creative Commons.

problems, and constraints of our own making. This structure is productive, serving not merely to motivate thinking and planning, but to also enable it. The problems we construct contain information that delineates the space of their possible resolutions, supporting the search for solutions. Assigning value to arbitrary ends confers utility on subgoals toward those ends, such that arguably costly activities, such as thinking and planning, can have positive utility, even if the ideas and plans have no other consequences for prediction or action. Our ability and willingness to think about whatever we like, liberated from the demands of functional outcomes, may pay off for our species in our ability to think of ideas we would not have thought of had we not been trying to achieve that particular, idiosyncratic goal. The ideas we generate can then be detached from the goals that originally inspired them, shared with others, and put to new, and sometimes transformative, ends.

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Declaration of interests

None declared by authors.

Resources

[i]www.nytimes.com/2021/04/30/world/europe/gareth-wild-parking-bromley-sainsbury.html

[ii]Investopedia.com

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