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Commentary

Modeling Intuition's Origins☆

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Computational models of intuition typically focus on describing cognitive implementations of intuitive decision-making. In this commentary, we highlight several ways in which formal models can be used to consider a different perspective: the evolutionary and social origins of intuition. Why should intuitions have come to function as they do? We consider three case studies that demonstrate how introducing evolutionary game theory into the psychological study of intuition can help answer questions about the origins of intuitive processes. These case studies demonstrate why we should expect (i) intuition to persist within a population even when other forms of cognition perform better; (ii) intuition to favor cooperation rather than selfishness; and (iii) intuitive cooperators to be trusted more than people who cooperate after carefully calculating costs and benefits.

Keywords: Intuition, Cooperation, Evolutionary game theory

As the many thoughtful articles in this special issue have suggested, the study of intuition is critical to understanding some of the most important facets of human nature and the mind, such as cognitive architecture (e.g., Thomson, Lebiere, Anderson, & Staszewski, 2015), expertise (e.g., Klein, 2015), and social behavior (e.g., Dhami, Belton, & Goodman-Delahunty, 2015). We echo the call for more computational approaches to studying this fascinating capacity (Hoffrage & Marewski, 2015): formal models can put informal verbal theories on more stable footing by forcing us to give clear mathematical formulations of vague psychological concepts. They can also make novel predictions that would not necessarily come out of simple a priori theorizing. Finally, formal models can help address some of the most fundamental theoretical questions in psychology, such as how the mind makes broad statistical inferences about the environment.

In this commentary, we argue that formal models are important not only for studying the psychological processes that are involved in intuitive cognition, but also for exploring the origins of those processes. A great deal has been written about the benefits of studying psychology through ultimate-level theories like the theory of evolution (e.g., Cosmides & Tooby, 1994). Formal models are particularly well suited for this task, a fact that we highlight in this commentary by describing recent work that brings formal evolutionary game theoretic models to bear on the topic of intuitive processing. The evolutionary game theoretic approach we describe is very general in scope, capturing dynamics that could play out both on the long timescale of genetic evolution (where adaptive traits spread via sexual reproduction) and the much shorter timescale of cultural evolution (where adaptive traits get imitated via social learning). Additionally, this approach makes use of both traditional analytic methods (e.g., differential equations and Nash equilibrium calculations) and agent-based computer simulations.

Complementing the fascinating work on the learning dynamics of trust already presented in the special issue (Juvina, Lebiere, & Gonzalez, 2015), we consider three case studies of how taking an evolutionary game-theoretic approach to studying intuition can answer interesting questions about the origins of this psychological capacity. These models formalize a particular approach to intuition based on heuristics and biases (Gilovich, Griffin, & Kahneman, 2002; Kahneman, 2011): they operationalize intuition as a cognitive capacity that is relatively fast and costless, but more error-prone and inflexible than deliberation. This characterization of intuition is far from complete, and does not capture

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other theories of intuitive processes (e.g. the "fast and frugal" approach whereby intuition is both fast and accurate (Gigerenzer & Todd, 1999)). Nonetheless, we feel it offers a useful starting point for exploring the origins of intuition, and helps to explain various empirical puzzles.

Why Would Intuition Persist in a Population?

The success of intuition versus deliberation is typically considered in the context of some particular exogenously determined (although potentially dynamic) environment. An important feature that is missing from this perspective, however, is *feedback*: the cognitive style employed by agents may itself influence the predictability of the environment and, therefore, the relative success of intuition versus deliberation (Cohen, 2005). What happens when we consider both styles of cognition coexisting in a population and interacting in (and with) a dynamic environment? This question can only be answered using an ultimate level of analysis, exploring how populations evolve as a function of their current makeup and properties of the environment.

Two recent papers have explored this question, one using evolutionary agent-based simulations (Tomlin, Rand, Ludvig, & Cohen, 2015) and the other using differential equations implementing "replicator dynamics" (Toupo, Strogatz, Cohen, & Rand, 2015). These papers use the domain of resource consumption and intertemporal choice as their framework for answering this question. Drawing on empirical work suggesting that intuitive human responses are typically faster and less sensitive (e.g. to the details of the current situation or to future consequences) than deliberative responses (Kahneman, 2011), and that intuitive processes tend to favor immediate over delayed rewards (McClure, Laibson, Loewenstein, & Cohen, 2004; Ward & Mann, 2000), the models include two different types of decision-making: "intuitive", which favors consuming resources immediately regardless of the agent's current energy level, and "deliberative", which engages in future planning and employs an optimal consumption policy. Thus, deliberation leads agents to make more effective use of the resources they find. However, the flexibility of deliberation requires time and effort, which means that deliberating agents may miss out on *acquiring* resources when competing with faster agents using intuition.

These models find that, in environments with limited resources, intuitive agents (those relying relatively more on intuition than deliberation) struggle to manage their consumption behavior and end up making costly errors that deliberative agents (those relying relatively more on deliberation than intuition) avoid. Crucially, however, the speed of intuitive processing can give intuitive agents an advantage when there is competition for resources. Moreover, intuitive agents' impulsive consumption behavior is less costly to them in resource-rich environments, which deliberative agents help to create through the invention of new technologies. As a result of this feedback between deliberative processing and environmental richness, intuition can be sustained in the population via a kind of free-riding mechanism: intuitive agents profit off the work of deliberative agents and then exploit them in head-to-head exchanges for resources. Once intuitive agents gain the upper hand, the environment collapses and becomes repopulated with deliberative agents who can thrive in sparser environments, and the cycle continues. Hence, to the extent that intuition is, at bottom, about more efficient processing speed, intuitive (and, therefore, fast) agents can eventually invade a population of agents that need more time to deliberate on whether and when to use resources—but only once those deliberative agents have enriched the environment enough to allow intuitive agents to succeed.

We speculate that this finding may help to explain why history tends to go through periodic phases of enlightenment and instability—and why, perhaps, we should not expect society to simply get more rational and deliberative over time. Furthermore, this kind of work may eventually aid our understanding of more practical kinds of consumption behaviors, such as society's exploitation of the environment or use of antibiotics. Lastly, the model could be expanded to consider other domain-specific tendencies to use intuition outside of consumption—an important topic explored in the special issue (Pachur & Spaar, 2015).

Why are People Intuitive Cooperators?

A recent body of experimental work suggests that people are more cooperative (i.e., willing to incur a short-term cost to benefit others) when they decide intuitively, as opposed to deliberatively (Rand, in press; Rand, Greene, & Nowak, 2012; Rand et al., 2014). This poses a puzzle: why should one kind of cognitive process be associated with more prosocial behavior? An answer can be found by combining the heuristics and biases perspective on intuition with what we know about cooperation's adaptive function.

From the perspective of selfish evolution, people who maximize their personal gains do better than people who give resources away when they can get away with defecting (e.g., in one-shot, anonymous interactions). But recognizing the strategic nature of the setting you are in sometimes requires cognitive flexibility. These two ideas were combined in a recent model of what happens when you inject dual-process agents, who sometimes use costless-but-inflexible intuition and sometimes stop to deliberate, into an evolutionary model (Bear & Rand, 2016). The virtual agents in this model face a mix of situations, some of which always favor selfish defection and others of which allow for the possibility of reciprocity (where cooperators can reap the benefits of reciprocal cooperation and defectors miss out on these benefits). Agents who stop to deliberate can distinguish these two contexts and flexibly adapt their cooperative decision to the kind of situation they are in, but this deliberation comes at a cost of inefficiency and speed. In contrast, agents who reason intuitively cannot discriminate these contexts and must rely on a heuristic to always cooperate or always defect in either kind of interaction, but they save on the cost of deliberation.

The model finds that, in most environments where reciprocity is reasonably likely, evolution favors intuitive cooperators who become selfish when they stop to deliberate and realize they can get away with defection. Moreover, agents never evolve to become more cooperative when they deliberate: those who