Title
Extraordinary entities: Insights into folk ontology from studies of lay people’s beliefs about robots

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 44(44)

Author
Weisman, Kara

Publication Date
2022

Peer reviewed

Extraordinary entities: Insights into folk ontology from studies of lay people's beliefs about robots

Kara Weisman (karaw@ucr.edu | kgweisman@gmail.com)
Developing Belief Network, Department of Psychology, University of California, Riverside
900 University Avenue, Riverside, CA 92521 USA

Abstract

Robots are extraordinary, category-defying entities. Machines that move autonomously, store and communicate information, display emotions, and cultivate social relationships pose a challenge to our most basic assumptions about what kinds of things exists in the world and how we should reason about them. As such, studies of lay people's beliefs about robots offer new insights into the ordinary functioning of folk ontologies. In this paper, I propose that there are two ontological questions that human reasoners must grapple with in making sense of robots, or any other entity: *Which kind of thing is it?* and *Which causal forces act on it?* Each question highlights a distinct way in which robots are extraordinary—albeit, not exceptional—entities for the human cognitive system. A meditation on the dynamic interplay between these two ontological questions provides a new theoretical framework for understanding conceptual change at both the individual and the cultural-historical level.

Keywords: folk biology; folk psychology; animate-inanimate distinction; concepts and categories; conceptual change; robots

Introduction

Robots are extraordinary entities. Unlike most artifacts, they move autonomously, store information, communicate, display emotions, and sustain extended social interactions. In certain moments, they seem to defy the fundamental distinction between animate beings and inanimate objects. The possibility of a machine with a mental life raises deep questions about animacy, agency, and personhood—and in recent years these questions have taken on new practical importance as robots and other artificial intelligences have been incorporated into many people's everyday lives. How do people make sense of these category-defying machines?

In this paper, I examine the ways in which lay people's beliefs about robots illuminate the ordinary functioning of folk ontologies more broadly. I propose that there are at least two distinct ontological questions that human reasoners must grapple with in making sense of any entity: *Which kind of thing is it?* and *Which causal forces act on it?* Drawing on empirical studies of lay people's beliefs about robots, I argue that each question highlights a distinct way in which robots are "extraordinary"—albeit, not exceptional—entities for the human cognitive system. Although these two ontological questions are distinct, they are intimately related both in principle, and, I argue, in human reasoning and conceptual development: Examining the dynamic interplay between categories (*Which kind of thing is it?*) and causal explanatory frameworks (*Which causal forces act on it?*) provides a new theoretical framework for understanding conceptual change at both the individual and the cultural-historical level.

Which kind of thing is a robot?

What most scholars seem to mean by examining robots as "extraordinary" targets for human reasoning is that it is difficult to classify robots as either animate beings or inanimate objects. This tension is illustrated in Figure 1A, where ROBOT straddles the boundary between inanimate objects (like books, forks, and rocks) and animate beings (like fish, platypuses, and humans).

Indeed, a long tradition of empirical work supports the idea that robots are difficult for people to classify as either animate or inanimate. On the one hand, one important feature of animate beings is that they are living, biological organisms. The vast majority of studies suggest that only very young children are at all confused about whether robots are living creatures in this sense; among older children and adults there appears to be widespread and stable consensus among lay people that robots are instead non-living machines (e.g., Broadbent et al., 2013; Chernyak & Gary, 2016; Friedman et al., 2003; Jipson et al., 2016; Severson, 2010; Okita & Schwartz, 2006; van Duuren & Scaife, 1996; Weiss et al, 2009). On the other hand, another important feature of animate beings is that they are intentional, goal-directed agents. The evidence strongly suggests that people of all ages are quite at ease with treating robots as planful agents with capacities for memory and reasoning (e.g., Bernstein & Crowley, 2008; Gary, 2014; Haslam et al., 2008; Kahn et al., 2012; Melson et al., 2009; Nigam & Klahr, 2000; Severson, 2010; Weiss et al., 2009). Further complicating this matter are the many mixed findings regarding people's tendency to construe robots as social partners—an understudied and undertheorized aspect of "animacy." Evidence for social-emotional construals of robots is more equivocal, and suggests that people's judgments seem especially likely to be influenced by developmental, cultural, and historical forces (e.g., Chernyak & Gary, 2016; Friedman et al., 2003; Gácsi et al., 2016; Gary, 2014; Haslam et al., 2008; Jipson et al., 2016; Kahn, Kanda, et al., 2012; Melson et al., 2009; Nigam & Kalhr, 2000; Severson, 2010; Weiss et al., 2009).

In other words, when it comes to what kind of thing a robot is, lay people appear to be quite clear on the fact that robots are not prototypical animate beings—but they do not appear to classify robots as inanimate objects, either.

Some have argued that social robots are a dramatic exception to an otherwise clear animate-inanimate distinction that they might come to constitute a "new ontological category" (Kahn & Shen, 2017), with lay people conceptualizing and interacting with robots as if they were somehow "half-living," in between" animal and artifact. A

In J. Culbertson, A. Perfors, H. Rabagliati & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual Conference of the Cognitive Science Society.*

key prediction from line of thinking is that robots are facilitating an unprecedented kind of historical conceptual change: Although current adults may continue to treat robots as mere exceptions to a two-way distinction between animate beings and inanimate objects, children growing up among sophisticated social robots will construct a system of categories that somehow accommodates their presence as "normal," e.g., a system in which the categories ANIMAL and ARTIFACT sit alongside a third category of equal status (perhaps, SOCIAL TECHNOLOGY).

I find this "new ontological category" hypothesis to be a deeply thought-provoking proposal—but I question the premise that robots are truly *exceptional* in their straddling of fundamental ontological categories, and the related conclusions that this is an example of unprecedented historical conceptual change. In Figure 1A, I have included three other entities that pose problems for the animate-inanimate distinction—germs, plants, and spirits—all of which predate the emergence of robots into human lives in the twentieth and twenty-first centuries. Plants, in particular, have been a crucial part of existence and survival throughout human history—yet in studies of animacy, life, and folk biological reasoning plants are notoriously challenging for young children to classify and reason about (e.g., Anggoro et al., 2008; Carey, 1985; Dellantonio et al., 2012; Hatano et al., 1993; Inagaki, 1996; Johnson & Carey, 1998; Leddon et al., 2008; Nguyen & Gelman, 2002; Opfer & Siegler, 2004) and construals of plants appear to vary substantially across cultural settings (ojalehto et al., 2017; Ross et al., 2003; Yorek et al., 2009). Likewise, spirits, gods, and other religious and supernatural beings have been part of the landscape of most human lives, but are also difficult to classify straightforwardly as "animate" (e.g., Shaman et al., 2018).

Nonetheless, robots may defy categorization in new and interesting ways—for example, robots seem to be considered both animate in some senses and inanimate in others (Kahn & Shen, 2017; Melson et al., 2009; Saylor et al., 2010), while germs, plants, and spirits might be considered neither animate nor inanimate (e.g., viruses reproduce and evolve but are biochemically inert on their own; ghosts are agents that are, by definition, no longer alive).

From this perspective, people's complex beliefs about the animacy status of robots highlight the importance of reconsidering the nature of the animate-inanimate distinction in folk ontologies of the world. There is no question that the animate-inanimate distinction is a meaningful one—but decades of empirical studies of people's understanding of robots underline the fact that this is not—and, I would argue, never has been—a clear, binary, all-or-nothing category boundary.

Which causal forces is a robot subject to?

Another way in which robots might be "extraordinary" is that robots appear to be affected by an unusual combination of causal forces: Like any other material thing, robots are subject to external physical forces (e.g., gravity, friction), but their behavior also appears to be driven by a subset of the internal causal forces that constrain and influence human and animal behavior.

The question *Which causal forces is it subject to?* is a different kind of ontological question from *What kind of thing is it?* Rather than delineating categories of things in the world, it concerns the causal structure of the world. Ontological questions about causal structure in turn raise epistemological questions about how to learn and reason about the entity in question—in psychological parlance, which explanatory frameworks, conceptual systems, or "folk theories" are appropriate? If an entity is subject to biological causal forces (e.g., illness, growth) then folk biology is likely to provide reasonable predictions and explanations of its behavior. But folk biology has little to offer when it comes to reasoning about the movement of billiard balls, or the reaction between baking soda and vinegar, for which (folk) physics and chemistry would be much more appropriate.

The empirical studies reviewed above suggest that lay adults view robots as subject primarily to psychological forces (e.g., perception, memory, goals), while children view robots as subject to both psychological and social forces (e.g., complex emotions, relationships). Only the youngest children in these studies appeared to view robots as subject to biological forces.

Thus, from relatively early in life, robots appear to occupy an unusual place in lay people's perceptions of the causal structure of the world—affected by psychological and perhaps social forces in the absence of biological constraints. Put another way, robots evoke folk psychology—and, for children, conceptual representations of the social world—without evoking folk biology. (Robots almost certainly also evoke folk physics, although this is not typically the focus of empirical studies.) This pattern is illustrated in Figure 1B.

This second perspective on folk ontologies—centered on people's perceptions of causal structure rather than their perceptions of category membership—has rarely been applied in previous scholarly work on robots, but I believe it has much to offer.

First, focusing on causal structure and causal explanatory frameworks situates reasoning in the context of action and interaction: In real-world encounters with robots, questions about causal structure (*What will the robot do next? What does it mean when the robot moves like that? How should I respond?*) are at least as important, and likely more urgent, than more abstract questions like *Is it animate or inanimate?*

Second, this approach highlights a different way in which robots are "extraordinary" entities: They evoke only a subset of the causal explanatory frameworks necessary for making sense of humans and other animals. Even as humans pursue goals and engage in social interactions, our behaviors are also driven by biological needs and constraints, as well as by gravity, friction, and other physical forces; a full account of human behavior would thus draw on all of these causal explanatory frameworks (and perhaps others). In contrast, any agentic or social behaviors enacted by robots are enacted in the absence of any biological constraints. Again, I would

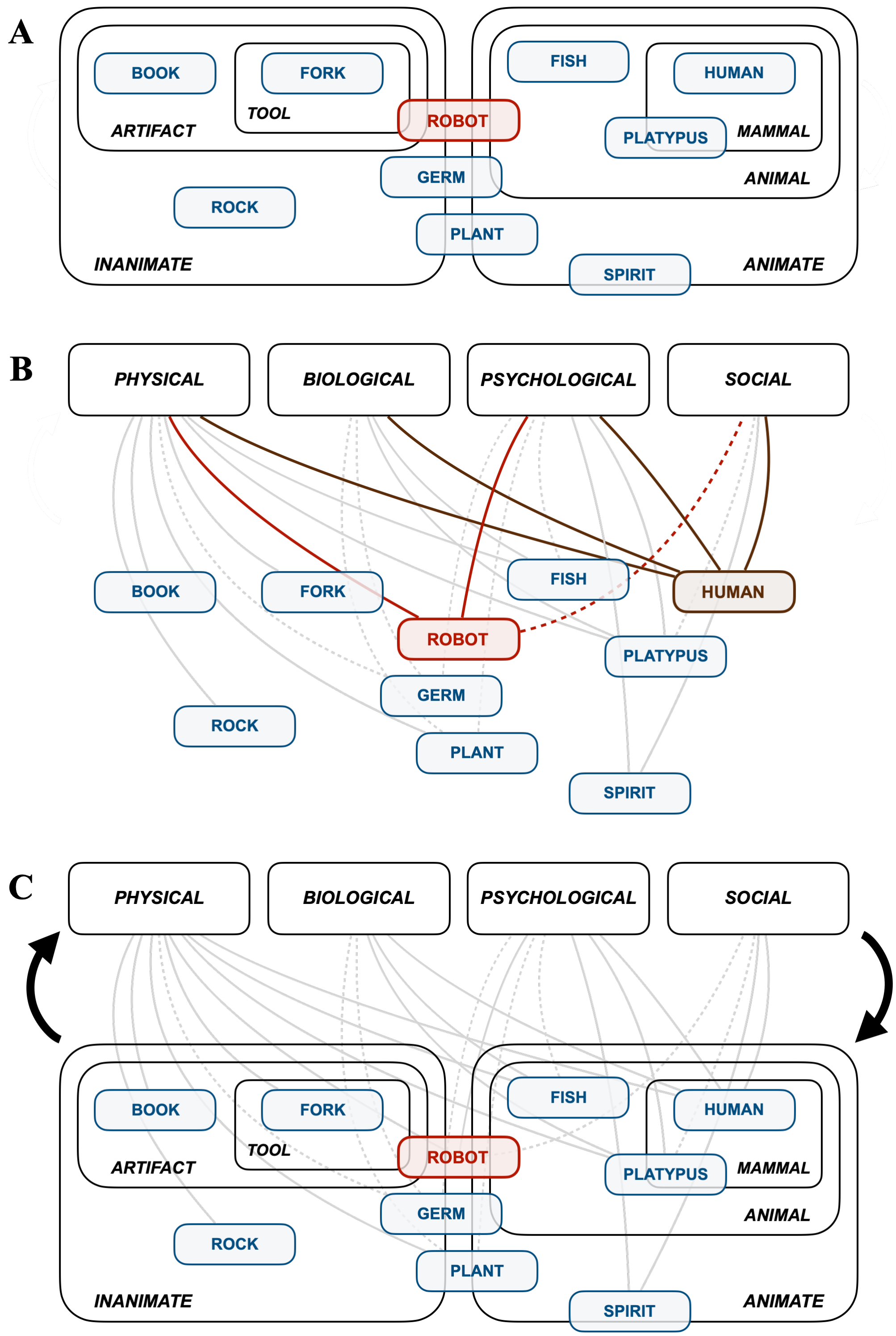

Figure 1: Three views of a folk ontological system for understanding robots and other entities: (A) An ontology focused on categories, driven by the question, *Which kind of thing is it?* Robots—along with germs, plants, and spirits—are unusual in that they are difficult to place on one side of the categorical boundary between inanimate objects and animate beings. (B) An ontology focused on causal explanatory frameworks, driven by the question, *Which causal forces is it subject to?* Humans are influenced and constrained by physical forces (e.g., gravity), biological forces (e.g., illness), psychological forces (e.g., goals), and social forces (e.g., relationships). Robots are unusual in that they are subject to physical, psychological, and perhaps social forces, but not biological forces. Spirits might be unique in being subject to psychological and social forces in the absence of biological or physical forces. (C) The two ontologies—capturing both categories and causal explanatory frameworks—in a cycle of mutual constitution.

argue that robots are not strictly exceptional in this regard: Gods and spirits, for example, are entities that might come to be perceived to occupy an even more unique niche in the causal structure of the world, being subject to psychological and social forces without being constrained by either biological or physical forces (Barlev et al., 2019; Shaman et al., 2018). Nonetheless, robots offer an unusual opportunity for people to reason about psychological and social causes in the absence of biological constraints—and, by extension, a rare chance for researchers to observe folk psychology and social reasoning in the absence of folk biology.

What could we learn from such observations? Consider the pairing of folk psychology and biology. If patterns of reasoning about the perceptions, beliefs, goals, and actions of robots were identical to psychological reasoning about humans—even as people decline to attribute biological properties to robots—this could be taken as evidence that folk psychology operates independently from folk biology, i.e., that these conceptual systems are to some degree encapsulated from each other. If, instead, people's folk psychological reasoning about robots diverged in reliable ways from their reasoning about humans, the divergences might highlight ways in which folk psychology and folk biology are coordinated in their application to humans: Folk biology might constrain the accuracy of human perception (e.g., human eyes see poorly at night), the reliability of human memory (e.g., retention of information is less reliable in the brains of humans that are very young or very old), the optimization of human reasoning (e.g., human brains do not operate at full capacity when they are sleep-deprived), or the kinds of intentions a human might hold (e.g., humans are unlikely to adopt goals that put their biological survival at risk). Finally, if people (mistakenly) applied biological constraints to robots in the course of reasoning about robots' minds and goals (e.g., by indicating that a robot might operate less effectively at night, or that it would be impossible for a robot to adapt a self-destructive goal), this might suggest that folk biology and folk psychology are so integrated in ordinary reasoning that people find them difficult to disentangle from each other. Beyond this, age-related differences in such response patterns could, in turn, shed new light on how the relationship between folk biology and folk psychology changes across development—a long-standing interest in the field of cognitive development (e.g., Carey, 1985; Erickson et al., 2010; Inagaki, 1997; Medin & Atran, 2004). These possibilities illustrate how empirical work on robots and other "extraordinary" entities that is grounded in an ontological interest in causal structure (rather than, or in addition to, category membership) could contribute to general theories of the cognitive architecture underlying more typical examples of reasoning.

This thought experiment also raises deep psychological questions about representations of causal structure in general. I outline three such questions below.

First: How do people coordinate, combine, or adjudicate among the many causal explanatory frameworks that may be appliable to robots, humans, or other entities—especially if these explanations conflict? Many cognitive scientists have written about the coexistence and coordination of multiple conceptual systems (e.g., Keil & Newman, 2009; Legare et al., 2012; Spelke, 2000), but relatively little empirical work has engaged with the fact that this kind of coordination problem is the rule, not the exception. The unusual subset of explanatory frameworks required to make sense of robots highlights the fact that in ordinary reasoning, lay people are constantly coordinating and adjudicating between a rather large number of causal explanatory systems—particularly when they reason about themselves and their fellow humans, whose behaviors might well be described and understood through any number of explanatory lenses (e.g., physics, chemistry, biology, psychology, sociology, and so on).

Second, and relatedly: What kind of causal structure might relate folk theories in different domains? Folk biology might constrain folk psychology along the lines of the hypothetical findings described earlier (e.g., by setting expectations about the limits of human perception, memory, reasoning, intentions, and other psychological phenomena)—but this relationship need not be symmetrical. This is to say, folk biology might well constrain folk psychology without folk psychology constraining folk biology; folk physics might constrain both folk biology and folk psychology without itself being constrained by either. Theories of a "hierarchy of sciences"—in which, e.g., biology depends on chemistry, which depends on physics, which depends on mathematics, etc. (Comte, 1854)—extend as far back as ancient Greece, and remain familiar enough in the modern day to feature in popular webcomics (https://xkcd.com/435). Hierarchies and dependencies among *folk* theories is an area ripe for future research, and studies of robots and other extraordinary entities may provide unique leverage into this topic.

Third: Is there a distinct folk theory of the social world, and can it operate independently of folk biology and folk psychology? In recent years, the possibility of a foundational "intuitive sociology"—perhaps encompassing folk theories of social groups, social hierarchies, kinship structures, institutional structures has gained some traction among cognitive developmental psychologists (e.g., Rhodes & Chalik, 2014; Shutts & Kalish, 2021; see also Hirschfeld, 2013). Others have floated the possibility of a distinct "core knowledge system" dedicated to detecting and reasoning about social partners from early in life (Spelke, Bernier, & Skerry, 2013; Spelke & Kinzler, 2007). I myself have argued for a distinction between the causal explanatory frameworks invoked in reasoning about goal-directed agents vs. social partners (Weisman, Dweck, & Markman, 2017). In all of these cases, however, establishing the boundaries of such a folk theory (or knowledge system), and distinguishing this domain from "folk psychology" has proved somewhat difficult; again, taking into account beliefs about extraordinary entities like robots may provide new ways to probe the distinctions and connections among the many components of human "social reasoning."

The dynamic interplay between categories and causal explanatory frameworks

Of course, categories and causal explanatory frameworks are not unrelated—indeed, the intimate connections between them have long been recognized in much of the foundational work on categories, concepts, and conceptual change (see, e.g., Carey, 1985, 2009; Chi, 2009; Keil, 1989, 1991; Murphy & Medin, 1985; among others).

Drawing on a metaphor frequently used in cultural psychology, I propose that categories and causal explanatory frameworks exist in a "cycle of mutual constitution" (Markus & Kitayama, 2010), as illustrated in Figure 1C. In one direction, a category boundary might help delineate the domain of an explanatory framework (e.g., folk biology must explain the behavior of humans, platypuses, fish, and any other members of the category ANIMAL). Conversely, an explanatory framework might help define a category boundary (e.g., the category ANIMAL should apply to anything that is subject to illness, growth, and any other causal forces in the domain of folk biology).

From this perspective, conceptual development might be understood as a cyclical process, through which refinements to a representation of causal structure might generate changes in category membership, changes in category membership might yield (further) refinements to representations of causal structure, and so on. For example, in the domain of folk biology, as a child gains a more sophisticated understanding of nutrition as fueling metabolic processes at the cellular level (rather than merely describing the process of eating and excreting food through the digestive system), this might

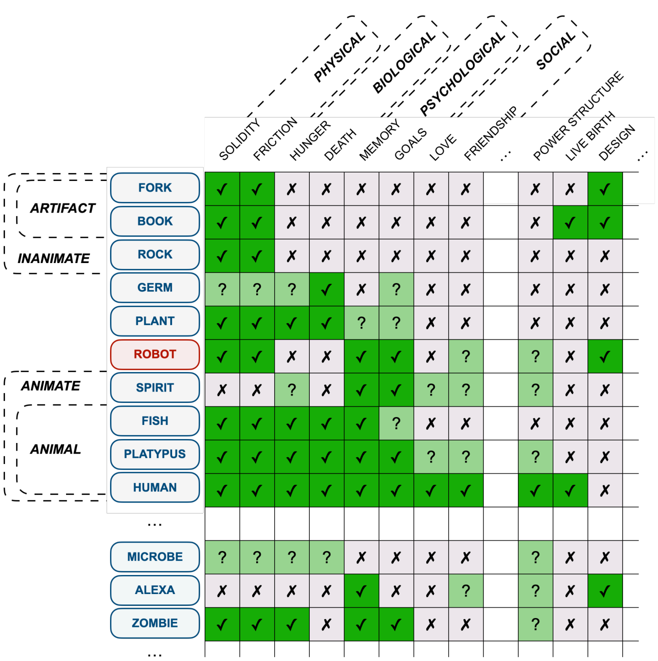

Figure 2: A (hypothetical) data matrix with rows of entities and columns of properties (including causal forces) sheds light on the dynamic interplay between categories and causal explanatory frameworks.

highlight the deep similarities between animals and plants, forming a new category of LIVING THING; in turn, having the category LIVING THING might lead to further refinements in folk biology, such as identifying other biological processes that might be redescribed at a more abstract level to apply to both animals and plants (e.g., reproduction). Likewise, cultural differences—across geographical setting and across historical time—might also be understood as the result of cycles of mutual constitution between categories and causal explanatory frameworks: Different cultural-historical settings are populated with different sets of entities, inherit different social-cultural values, and have available to them different linguistic tools for describing and communicating about the world—all of which might shape the construction and revision of categories and explanatory frameworks over time and space.

Thus, the rise of robots in modern life offers a unique case study of conceptual construction and perhaps conceptual change, both at the individual level (*What happens when a person encounters this extraordinary entity?*) and at the historical level (*What happens when a society encounters this extraordinary entity?*) (see Kahn & Shen, 2017; Nass et al., 1994; Turkle, 1984). On the one hand, the dynamic interplay between categories and causal explanatory frameworks could constrain construals of robots: For example, if a person (or a society) classifies robots as inanimate objects and understands inanimate objects to be categorically unconstrained by social causal forces, that person (or society) might deduce that robots should not be construed or treated as social partners. Alternatively, this cycle of mutual constitution could effect a reconfiguration of ontological categories: For example, if a society (or a person) bears witness to robots who appear, convincingly, to be subject to psychological and social forces but not biological forces, and if this is a new niche in the causal structure of the world, that society (or person) might construct a new category of entities comprised of social robots (Kahn & Shen, 2017).

I find this easiest to think about in the form of a hypothetical data matrix (Figure 2). In this matrix, both categories and causal explanatory frameworks can be thought of as "clusters" of vectors with similar patterns of entity-property values: categories as clusters of entities (e.g., INANIMATE, ANIMATE, as depicted on the left side of Figure 2), and explanatory frameworks as clusters of causal forces and other properties (e.g., PHYSICAL, BIOLOGICAL, and so on, as depicted at the top of Figure 2).

When a person or a society first encounters a new kind of entity—be it robots, microscopic organisms, disembodied artificial intelligences like Amazon's "Alexa" or Apple's "Siri," or fictional creatures like zombies—the properties of these entities might highlight new ways of grouping together entities, or might draw attention to additional properties that are crucial for reasoning about different kinds of entities (Festerling & Siraj, 2020). Likewise, drawing attention to additional properties—such as being subject to hierarchical power structures, giving birth to live young, or having been designed—might pick out additional relevant causal explanatory frameworks (e.g., frameworks for reasoning about social groups, mammals, or artifacts), further differentiate sub-categories of entities (e.g., MAMMAL, ARTIFACT), or pick out new categories of entities altogether. In other words, the cycle of mutual constitution between clusters of entities (categories) and clusters of properties (explanatory frameworks) might be redescribed as a state of affairs in which any change to the matrix connecting entities to properties has the potential to cause changes that propagate throughout the matrix. The nature and extent of these changes likely depends on the prior knowledge and conceptual structures embedded in the matrix (as well as auxiliary features of the individual or society in question, such as domain-general cognitive abilities, vocabulary and other aspects of language, broader cultural values, and so on). This metaphor closely resembles the data structures and computational processes employed in deep neutral networks and other unsupervised learning approaches to modeling category structure (e.g., Saxe et al., 2019)—which may hint at a particularly productive means of continuing to advance our understanding of conceptual change in these domains.

In sum, rather than robots intervening on otherwise static representations of the category structure and causal structure of the world, I propose that robots and other "extraordinary" entities reveal an ongoing, dynamic interplay between these representations. This cycle of mutual constitution may be a key part of what allows humans to navigate efficiently through our daily lives while retaining the cognitive flexibility to reason about a world in flux—a universe that continues to reveal to each person and to each society deeper complexities and new possibilities.

Conclusion

The possibility of artificially intelligent, socially sophisticated robots has fascinated scholars, storytellers, and others for nearly a century, and this fantasy is now closer than ever to reality. The rise of robots raises a host of questions with both philosophical and practical implications. Are robots capable of functioning as doctors, teachers, and caregivers, or even as friends, lovers, and family members? Is it possible, or ethical, for humans to create a machine that thinks and feels? What would such a machine reveal about what it means to be alive, conscious, intelligent, and human? How would this kind of being fit into—or possibly reshape—our social lives and moral commitments?

Time will tell how lay people's folk ontologies do or do not stretch to accommodate these untraditional social partners. In the meantime, continuing to document our developing relationships with this new presence in the world has the potential to shed new light on the nature and flexibility of human social reasoning and cognition more broadly.

Acknowledgements

Thanks to Ellen Markman, Carol Dweck, Hyowon Gweon, Arber Tasimi, Rebecca Saxe, and Rebekah Richert for their feedback on earlier versions of the argument presented in this paper. During the time spent working on current and earlier versions of this paper the author was supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE114747, by a William R. & Sara Hart Kimball Stanford Graduate Fellowship, and by the John Templeton Foundation under Grants No. 55427 and No. 61542.

References

Anggoro, Waxman, Medin, (2008). Naming practices and the acquisition of key biological concepts: Evidence from English and Indonesian. *Psychol Sci*, *19*(4).

Barlev, Mermelstein, Cohen, German (2019). The embodied God: Core intuitions about person physicality coexist and interfere with acquired Christian beliefs about God, the Holy Spirit, and Jesus. *Cogn Sci*, *43*(9).

Broadbent, Kumar, Li, Sollers, Stafford, MacDonald, Wegner (2013). Robots with display screens: A robot with a more humanlike face display is perceived to have more mind and a better personality. *PLoS ONE*, *8*(8).

Carey (1985). *Conceptual Change in Childhood*. MIT.

Carey (2009). *The Origin of Concepts*. Oxford.

Chernyak, Gary (2016). Children's cognitive and behavioral reactions to an autonomous versus controlled social robot dog. *Early Ed Dev*, *9289*.

Chi (2009). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In Vosniadou (Ed.), *Handbook of Research on Conceptual Change*. Erlbaum.

Comte (1854). *System of Positive Polity: or System of Sociology*.

Dellantonio, Innamorati, Pastore (2012). Sensing aliveness: An hypothesis on the constitution of the categories "animate" and "inanimate." *Int Psychol Behav Sci*, *46*(2).

Erickson, Keil, Lockhart (2010). Sensing the coherence of biology in contrast to psychology: Young children's use of causal relations to distinguish two foundational domains. *Ch Dev*, *81*(1).

Festerling, Siraj (2020). Alexa, what are you? Exploring primary school children's ontological perceptions of digital voice assistants in open interactions. *Hum Dev*, *64*(1).

Friedman, Kahn, Hagman (2003). Hardware companions? What online AIBO discussion forums reveal about the human-robotic relationship. *CHI 2003*, *5*.

Gary (2014 thesis). *Adults' Attributions of Psychological Agency, Credit, and Fairness to a Humanoid Social Robot*.

Gácsi, Kis, Faragó, Janiak, Muszynski, Miklósi (2016). Humans attribute emotions to a robot that shows simple behavioural patterns borrowed from dog behaviour. *Comp Hum Behav*, *59*.

Haslam, Kashima, Loughnan, Shi, Suitner (2008). Subhuman, inhuman, and superhuman: Contrasting humans with nonhumans in three cultures. *Soc Cog*, *26*(2).

Hatano, Siegler, Richards, Inagaki, Stavy, Wax (1993). The development of biological knowledge: A multi-national study. *Cog Dev*, *8*(1).

Hirschfeld (2013). The myth of mentalizing and the primacy of folk sociology. In Banaji, Gelman (Eds.), *Navigating the*

Social World: What Infants, Children, and Other Species Can Teach Us. Oxford.
Inagaki (1996). Young children's recognition of commonalities between animals and plants. *Ch Dev*, *67*(6).
Inagaki (1997). Emerging distinctions between naive biology and naive psychology. *New Dir Child Adolesc Dev*, *75*.
Jipson, Gülgöz, Gelman (2016). Parent-child conversations regarding the ontological status of a robotic dog. *Cog Dev*, *39*.
Johnson, Carey (1998). Knowledge enrichment and conceptual change in folkbiology: evidence from Williams syndrome. *Cog Psychol*, *37*(2).
Kahn, Kanda, Ishiguro, Freier, Severson, Gill, et al. (2012). "Robovie, you'll have to go into the closet now": children's social and moral relationships with a humanoid robot. *Dev Psychol*, *48*(2).
Kahn, Shen (2017). NOC NOC, who's there? A new ontological category (NOC) for social robots. In Budwig, Turiel, Zelazo (Eds.), *New Perspectives on Human Development*. Cambridge.
Keil (1989). *Concepts, Kinds, and Cognitive Development*.
Keil (1991). The emergence of theoretical beliefs as constraints on concepts. In Carey, Gelman (Eds.), *The Epigenesis of Mind*. Erlbaum.
Keil, Newman (2009). Two tales of conceptual change: What changes and what remains the same. In Vosniadou (Ed.), *Handbook of Research on Conceptual Change*. Erlbaum.
Leddon, Waxman, Medin (2008). Unmasking "alive:" Children's appreciation of a concept linking all living things. *J Cog Dev*, *9*(4).
Legare, Evans, Rosengren, Harris (2012). The coexistence of natural and supernatural explanations across cultures and development. *Ch Dev*, *83*(3).
Markus, Kitayama (2010). Cultures and selves: A cycle of mutual constitution. *Pers Psychol Sci*, *5*(4).
Medin, Atran (2004). The native mind: biological categorization and reasoning in development and across cultures. *Psychol Rev*, *111*(4).
Melson, Kahn, Beck, Friedman, Roberts, Garrett, Gill (2009). Children's behavior toward and understanding of robotic and living dogs. *J App Dev Psychol*, *30*(2).
Murphy, Medin (1985). The role of theories in conceptual coherence. *Psychol Rev*, *92*(3).
Nass, Steuer, Tauber (1994). Computers are social actors. *CHI 94*.
Nigam, Klahr (2000). If robots make choices, are they alive?: Children's judgements of the animacy of intelligent artifacts. *Proc CogSci Soc*.
Nguyen, Gelman (2002). Four and 6-year olds' biological concept of death: The case of plants. *Br J Dev Psychol*, *20*(4).
ojalehto, Medin, García (2017). Conceptualizing agency: Folkpsychological and folkcommunicative perspectives on plants. *Cog*, *162*.
Okita, Schwartz (2006). Young children's understanding of animacy and entertainment robots. *Intl J Humanoid Robotics*, *3*(3).
Opfer, Siegler (2004). Revisiting preschoolers' living things concept: A microgenetic analysis of conceptual change in basic biology. *Cog Psychol*, *49*(4).
Rhodes, Chalik (2014). The interplay between intuitive psychology and intuitive sociology. *Br J Dev Psychol*, *32*.
Ross, Medin, Coley, Atran (2003). Cultural and experimental differences in the development of folkbiological induction. *Cog Dev*, *18*(1).
Saxe, McClelland, Ganguli (2019). A mathematical theory of semantic development in deep neural networks. *PNAS*, *166*(23).
Saylor, Somanader, Levin, Kawamura (2010). How do young children deal with hybrids of living and non-living things: The case of humanoid robots. *Br J Dev Psychol*, *28*(4).
Severson (2010 thesis). *Thinking as or thinking as if: Children's and young adults' conceptions of a robot dinosaur in relation to natural and artifactual entities*.
Shaman, Saide, Richert (2018). Dimensional structure of and variation in anthropomorphic concepts of God. *Ront Psychol*, *9*.
Shutts, Kalish (2021). Intuitive sociology. *Adv Child Dev Behav*, *61*.
Spelke (2000). Core knowledge. *Am Psychol*, *55*(11).
Spelke, Bernier, Skerry (2013). Core social cognition. In Banaji, Gelman (Eds.), *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us*. Oxford.
Spelke, Kinzler (2007). Core knowledge. *Dev Science*, *10*(1).
Turkle (1984). *The Second Self: Computers and the Human Spirit*. Simon and Shuster.
van Duuren, Scaife (1996). "Because a robot's brain hasn't got a brain, it just controls itself": Children's attributions of brain related behaviour to intelligent artefacts. *Euro J Psychol Ed*, *11*(4).
Weisman, Dweck, Markman (2017). Rethinking people's conceptions of mental life. *PNAS*, *114*(43).
Weiss, Wurhofer, Tscheligi (2009). "I love this dog"- children's emotional attachment to the robotic dog AIBO. *Intl J Soc Robotics*, *1*(3).
Yorek, Şahin Aydin (2009). Are animals "more alive" than plants? Animistic-anthropocentric construction of life concept. *Eurasia J Math Sci Tech Ed*, *5*(4).