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Concepts and folk theories

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Abstract

Human cognition is characterized by enormous variability and structured by universal psychological constraints. The focus of this chapter is on the development of knowledge acquisition because it provides important insight into how the mind interprets new information and constructs new ways of understanding. We propose that mental content can be productively approached by examining the intuitive causal explanatory "theories" that people construct to explain, interpret, and intervene on the world around them, including theories of mind, of biology, or of physics. A substantial amount of research in cognitive developmental psychology supports the integral role of intuitive theories in human learning and provides evidence that they structure, constrain, and guide the development of human cognition.

Introduction

Human minds are dazzling in their variety and plasticity, and nowhere is this more apparent than in the contents of the mind. What a person knows and believes is highly contingent on experience and enormously flexible in the face of competing sources of information. Bodies are construed as partible in Melanesia (Strathern, 1988), mountains as agentive in Peru (de la Cadena, 2010), and human origins as the result of divine intervention in the United States (Evans, 2000). School children in Michigan believe that dancing in front of an open freezer will help ensure a snow day, whereas school children in Iowa believe placing a spoon under their pillow will do the trick. Surely no two individuals hold precisely the same beliefs. It is perhaps not surprising, then, that many scholars have avoided studying the content of belief systems--in favor of processes, structures, functions, or brain regions that are (believed to be) more stable, predictable, or universal. Nonetheless, in this chapter we focus precisely on mental content, because the mental representations that humans use to structure experience provide rich insights into how mind mediates world.

The vast and unwieldy topic of mental content can be fruitfully approached by examining the intuitive "theories" that people construct, including theories of mind, of biology, or of physics. Intuitive theories are not scientific theories–they are not formal, explicit, precise, or experimentally tested. Intuitive theories are implicit and imprecise, but like scientific theories, intuitive theories have broad implications: they organize experience, generate inferences, guide learning, and influence behavior and social interactions. Most centrally, intuitive theories are *causal* and *explanatory*. Indeed, explanatory systems of knowledge are integral to human cognition and learning. A recurring theme is that intuitive theories are not neutral or passive snapshots of experience; they embody *cognitive biases* that influence thought and action.

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Overview

This chapter reviews recent research in developmental, cognitive, and cultural psychology that examines intuitive theories and their implications. In so doing, we will trace some important cognitive biases that structure and constrain their development. We also highlight the value of a developmental approach that examines how these theories emerge and change in childhood. The chapter is organized as follows. First, we briefly review the notion that knowledge is organized into commonsense theories. We then present two case studies of well-researched theories, in the domains of mind and living kinds. Each illustrates the components of a theory (ontology, causal principles, coherence, resistance to counterevidence, and hypothesized unobservables). Next, we discuss an overarching issue that stems from the case studies: the co-existence of multiple explanatory frameworks. We end with a summary and discussion of the primary issues.

Concepts in theories

Knowledge and beliefs are actively constructed on the basis of an interplay between data and theory (Waxman & Gelman, 2010). Humans possess exquisitely well-tuned capacities to track and reason about sensory and perceptual evidence (using statistical and probabilistic learning), yet at the same time construct powerful causal theories (with domain-specific ontological commitments and coherence) that impose order on the evidence and guide interpretations. Knowledge cannot be reduced to one or the other approach (bottom-up or top-down) alone.

Evidence for the data-analytic capacity of humans comes from research showing that people are surprisingly skilled at noting and remembering patterns in experience. Passively listening to a 2-minute sequence of nonsense syllables (badukibiramu...) is sufficient for college students and 8-month-old babies to extract repeated regularities, such that certain sequences of syllables are heard as “words”, and recognized in isolation (Saffran, Aslin, & Newport, 1996). This unsupervised (and untutored) learning does not require conscious awareness, and indeed appears to involve wholly separate neural signatures from conscious judgments of familiarity (Turk-Browne, Scholl, Chun, & Johnson, 2009). Furthermore, perceptual experience trains the content of categories over development. For example, children start out quite open as to which categories they can learn, but then over time experience greater difficulty making discriminations to which they don't have experience. Thus, for example, infants are at first able to make discriminations across the world's languages but by about 12 months of age are only able to discriminate the phonemes in the native language they are hearing (Werker & Desjardins, 1995). Likewise, infants are initially equally skilled at distinguishing faces across different racial and ethnic groups, but by about 9 months of age are more skilled at distinguishing faces within the racial/ethnic group to which they have had exposure (Kelly et al., 2007). Thus, perceptual cues and perceptual learning are important mechanisms for acquiring culturally specific norms and experiences.

Some have concluded, incorrectly in our view, that the impressive capacity to attend to and learn from sensory/perceptual input suggests that building a mind is an engineering problem in which the task is to take sensory input as the building blocks to increasingly complex structures (Sloutsky, Kloos, & Fisher, 2007). It is important to note, however, that demonstrating sensitivity to perceptual cues does not demonstrate a lack of sensitivity to theories (Waxman & Gelman, 2009).

Briefly, what do we mean by an intuitive theory? Components of a theory include ontological commitments, causal laws, coherence, resistance to counter-evidence, and unobservable or hidden constructs (Carey, 1985; Wellman & Gelman, 1998). Ontological commitments specify what sorts of entities participate in a theory. Thus, a person can be variously construed as a sentient being with thoughts and desires [theory of mind], a living member of the species Homo Sapiens [theory of biology], a solid object with weight, mass, and momentum [theory of physics], a soul encased in a temporary physical home [theory of religion], etc. Causal laws provide framework cause-effect mechanisms that foster predictions and explanations (e.g., in a theory of mind, thoughts and beliefs motivate human behavior; in a theory of physics, one solid object colliding into another results in movement). Coherence refers to the interrelatedness of different concepts and beliefs. Thus, changing one belief in a theory would lead to a domino effect of other changes in belief (see Carey, 2009, for examples of coherence in historical and childhood conceptual change). This is related to the idea that deeply held theories tend to be resistance to counterevidence (e.g., if I think the world is flat, I will reinterpret evidence to fit this view; Karmiloff-Smith & Inhelder, 1978). Finally, theories entail unobservable processes and entities, such as gravity, quarks, essences, and phlogiston.

Statistical cues do not compete with theory construction; they are input to theory construction (Waxman & Gelman, 2009). An especially compelling example of this relationship is that statistical regularities provide important cues to infer causation. For example, Gopnik and colleagues presented preschool children with a mechanical device that lights up and plays music when toys of a certain type (“blickets”) are placed on it (Gopnik et al., 2001). The child's task is to determine which toys are blickets, given only patterns of co-occurrence between toy placement and causal effects (machine lighting up and playing music). Children are remarkably skilled at drawing sophisticated inferences about causality on the basis of these cues. For example, if the machine lights up when two objects (A and B) are placed on it simultaneously, then the machine fails to light up when object A alone is placed on it, preschool children infer that B is a blicket. However, that these are causal inferences, and not just associative learning, is clear in that mechanism information is always decisive. Only associations that have a plausible underlying mechanism are deemed relevant (for example, if a block is placed near the machine but not without physical contact, a child no longer makes causal inferences). Children's judgments are also influenced by whether an action is performed by the self or by another person (Kushnir, Wellman, & Gelman, 2009), reflecting the intuitive assumption that one's own actions are more agentive and effective.

There are three primary arguments for the significance of theories in everyday mental representations:

1. Similarity and frequency counts are *insufficient* to characterize human concepts and categories. Human concepts reflect human interests, needs, and goals (Murphy & Medin, 1985). As William James noted (1890/1981): “We carve out order by leaving the disorderly parts out... We carve out everything, just as we carve out constellations, to suit our human purposes.” Beliefs about causality influence decisions regarding which items belong in a category (Ahn, 1998; Rehder & Kim, in press). When both statistical cues and causal information are available, even young children attend to both (Schulz, Bonawitz & Griffiths, 2007). So, for example, if statistical cues compete with an a priori belief that illness has a physical, not psychological basis (e.g., a rabbit gets sick after being scared), children are influenced by the causal belief system as well as the statistical cues. As with scientists, children have a bias to accept confirmatory evidence, but sufficient counter-evidence will have a role (Legare, Gelman, & Wellman, 2010). Furthermore, use of statistical cues varies depending on one's understanding of the sampling process (e.g., Was the sample selected randomly or intentionally? Was the sample selected with the goal of learning about the sample, or with the goal of teaching about the sample?), and even infants appreciate this (Xu & Tenenbaum,

2007; Rhodes, Gelman, & Brickman, 2010; Gweon, Tenenbaum, & Schulz, 2010; Kushnir, Xu, & Wellman, 2010).

2. Attention to causal structure is apparent early in ontogeny. Starting in early childhood, children actively work to comprehend the world around them; they seek to understand how and why things happen by asking causal questions (Frazier, Gelman, & Wellman, 2009), making predictions (Shultz, 1982), engaging in more or less effective interventions (Kushnir & Gopnik, 2005), and providing explanations for events and actions (Callanan & Oakes, 1992; Legare, Gelman, & Wellman, 2010; Wellman, Hickling, & Schult, 1997). A growing developmental literature now provides considerable insight into how knowledge of causation develops (Baillargeon, 2002; Cohen & Oakes, 1993; Gopnik & Wellman, 1994; Leslie, 1995). Among the earliest concepts that children develop are non-obvious, invisible, theorized constructs such as mental states (Wellman, in press), ontological distinctions (Booth, Waxman, & Huang, 2005), causation (Gopnik, Sobel, Schultz, & Glymour, 2001), function (Asher & Kemler-Nelson, 2008), internal parts (Diesendruck, 2001), essences (Gelman, 2003), and abstract kinds (Brandone, Cimpian, Leslie, & Gelman, in press).

3. Language learning--arguably a hallmark of human cognition--requires social understanding (Sabbagh & Baldwin, 2005). Thus, one cannot acquire language without a capacity to read others' intentions (Tomasello, 2001), judge a speaker's credibility (Koenig & Woodward, 2010), and distinguish representations from objects represented (Preissler & Carey, 2004). Learning words does not simply entail low-level associations between word and referent (Waxman & Gelman, 2009); children selectively consider information that supports the model that a speaker is intentionally naming in order to convey a conventional label. Thus, for example, if the child is attending to one object while the adult labels another, even 16-monthold s will figure out that the label attaches to the object the adult was looking at, and not the focus of the child's own attention (Baldwin, 1993). (It is interesting to note, in this regard, that demonstrations of word learning in non-human species, e.g., Kaminski, Call, & Fischer, 2004, generally have not examined whether the word-learning process is like that of human children, in being tied to these social capacities (Markman & Abelev, 2004).)

As noted earlier, one of the key components to an intuitive theory is a causal framework. From early childhood onward, humans are causal thinkers, looking for intervening mechanisms to explain how and why things happen (Gopnik & Schulz, 2007). The centrality of causation can be seen both in sophisticated causal predictions and in rich deployment of causal explanation (Keil, 2006).

Interestingly, the process of explaining may itself alter our cognitive representations and constitute a mechanism for learning (Chi et al., 1994; Lombrozo, 2006; Siegler, 2002; Wellman & Liu, 2007). Children can be more accurate when explaining than predicting (Legare, Wellman, & Gelman, 2009). They also learn more when they are asked to explain events, than when they are only given feedback about the accuracy of their predictions (Amsterlaw & Wellman, 2006). At the same time, both adults and especially children overestimate the detail and depth of their explanatory knowledge (Keil, 2003; Mills & Keil, 2004).

Thus, explanation has a central yet inconsistent role: on the one hand, children are active explanation-seekers and readily request and provide causal explanations. Yet on the other hand, they are poor at assessing their own causal knowledge and think they understand things when they do not.

In light of the latter (overestimating one's causal knowledge), an important question is: what motivates the explanatory process? Why seek explanations if one (incorrectly) believes that one already has a deep causal understanding? A key factor turns out to be inconsistency: learners are especially motivated to construct an explanation when there is an inconsistency to be reconciled or a problem to be solved (Legare, Gelman, & Wellman, 2010). Specifically, inconsistencies prompt exploratory, hypothesis-testing behavior. Research with preschool children has examined the relationship between explanation and exploratory behavior following consistent versus inconsistent outcomes. For inconsistent outcomes only, the kind of explanation children provide informs the kind of exploratory behavior they engage in, and the extent to which children modify and generate new hypotheses when faced with inconsistent evidence (Legare, in press). Importantly, exploratory behavior does not exclusively reflect children's explanatory hypotheses; instead, causal explanation and exploratory behavior likely operate in tandem as hypothesis-generating and hypothesis-testing mechanisms. As Karmiloff Smith and Inhelder (1978, p. 207) note, “action sequences are not merely a reflection of the child's implicit theories. The very organization and reorganization of the actions themselves, the lengthening of their sequences, their repetition and generalized application to new situations give rise to discoveries that will regulate the theories, just as the theories have a regulating effect on the action sequences.” Thus, research on this interplay provides insight into a mechanism by which explaining inconsistent evidence may inform causal cognition (Legare, in press).

Although causal understanding can be understood in general terms, theories are by their very nature domain-specific. We turn next to an examination of intuitive theories in two domains, psychology and biology.

Theory of mind

Core theories emerge early in childhood, persist across widely varying cultural contexts, and concern (evolutionarily) privileged domains of human cognition (Wellman & Gelman, 1998). Perhaps the most thoroughly studied intuitive theory is that known as “theory of mind” – the ontological, causal beliefs we have regarding the motivations, goals, intentions, and consequences of human behavior. As many have observed (e.g., Wellman, in press), humans do not think about actions in terms of overt behaviors alone (indeed, doing so would result in profound difficulties navigating the social world), but rather in terms of unobserved (theorized) mental constructs: beliefs, desires, intentions, goals. The ability to relate the simple action sequences produced by perceptual cues to the cognitive beliefs of a perceived actor facilitates the emergence of more complex representations of intention, and in turn, the ability to reason about future behavior.

Among the exciting discoveries of cognitive science in the last two decades is the richness of children's capacity to engage in “mind-reading” (see Wellman, in press, for review). From birth, infants prefer to look at faces (Johnson, 1992), to attend to voices (Vouloumanos & Werker, 2007), and to imitate conspecifics (Meltzoff, 2005). Within the first year of life, infants appreciate goal-directed action as distinct from mere movement (e.g., when viewing a hand reaching toward object A at location X, 5-month-old infants interpret the action as a reach toward A, not a movement toward X; in contrast, an inanimate stick making the same motion is interpreted as a movement toward X; Woodward, 2009). By 11-12 months of age, infants point to direct others’ attention (Bates, Camaioni, & Volterra, 1975; Tomasello, Carpenter, & Liszkowski, 2007), monitor others’ gaze (Moll & Tomasello, 2004), and engage in social referencing (e.g., avoiding going over a visual cliff if the parent indicates fear; Feinman, 1992). They learn differently from contexts in which the adult first engages their attention, signaling that the context is a pedagogical one (Csibra & Gergeley, 2009). At 9-18 months, infants distinguish when someone is unwilling to hand over a toy from when she is unable (Behne, Carpenter, & Tomasello, 2005). By 18 months, children imitate intended actions rather than observed actions (e.g., when watching someone who attempts to pull apart a toy but fails to do so, the child imitates the (unfulfilled) goal action, whereas virtually no imitation takes place when the same action is demonstrated by a machine; Meltzoff, 1995). During the second year of life, children show a propensity to share, cooperate, and distribute resources equitably (Warneken & Tomasello, 2009). They engage in altruistic action. All of these capacities provide an important foundation for social interchanges and an ability to learn from others.

At the same time, there are striking developmental changes in young children's theory of mind. From 3 to 5 years of age, children undergo dramatic improvement in their ability to reason about false beliefs (e.g., believing that a toy is hidden in the closet when it's actually under the bed). In classic tests of false belief, 3-year-olds show a reality bias, for example reporting that someone who wasn't watching when the toy was moved from the closet to under the bed nonetheless will believe it to be under the bed and will search there when given an opportunity (Perner, Leekam, & Wimmer, 1987). By 5 years of age, children generally pass this test, indicating a capacity to hold in mind alternative mental construals. Along with the capacity to reason about false belief comes an ability to reason about deception. Whereas 3-year-olds have great difficulty understanding deception, 5-year-olds become able to deploy it appropriately, as needed (Talwar & Lee, 2008). Individuals with autism spectrum disorder continue to fail tasks of false belief, permit a revealing contrast of what a theory of mind entails–and how different behavior is without it. A further complication to this developmental story is that infants seem to appreciate false belief when assessed using measures of looking time (Kovács, Téglás, & Endress, in press; Onishi & Baillargeon, 2005). Although there is lively debate to explain the discrepancy between traditional measures with preschoolers and looking-time measures with infants, one possibility is that implicit sensitivity emerges before explicit awareness (see also Hood, Carey, & Prasada, 2000, for example of implicit awareness preceding explicit performance, when reasoning about gravity).

A thriving controversy concerns how much of theory of mind is exclusively human (Povinelli & Vonk, 2003; Call & Tomasello, 2008). Tomasello (2009) makes a thought-provoking distinction between human cooperation and non-human competition. Chimpanzees are amazingly skilled at taking into account others' perspective when engaged in competitive action, yet they are much less skilled than human children in cooperating with others and do not seem to engage in altruism or collaboration as do even young humans (Tomasello, 2009). The human propensity to cooperate leads to pedagogy and imitation to indicate group membership, and ultimately to a "cultural ratcheting" effect whereby human artifacts and cultural practices become increasingly complex over time.

Another important comparative example concerns the basis and extent of learning from others. For example, whereas humans reproduce the particular actions used by a model (imitation), chimpanzees reproduce only the outcomes (emulation) (Tennie, Call, & Tomasello, 2006). The human capacity to learn from others facilitates development at both the individual and cultural level (Tomasello, 2008; but see Whiten, Spiteri, et al., 2007, for evidence of cultural transmission in chimpanzees). This ability helps children to become socialized, permits culture to be transmitted across generations, and underlies progress in science and technology. However, in certain key contexts, it also leads to a fascinating reversal whereby chimps outperform humans. Specifically, children will reproduce actions that are clearly irrelevant to the functioning of an object (known as "overimitation"), whereas chimpanzees appropriately limit their actions to those that are functionally relevant (Lyons, Young, & Keil, 2007; Want & Harris, 2002; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009).

Some have suggested that over-imitation is a foundation for ritual action. Given that humans are inveterate 'mind-readers' (forever wondering what intentions motivate the behavior of others), it is of particular interest that rituals, unlike much of intentional action, do not appear to be motivated by individual goals or belief states. Indeed, ritualized actions pose a unique challenge to theoretical accounts of teleological and causal reasoning because they are irreducible to any set of intentional meanings (Humphrey & Laidlaw, 1994) and technical or causal motivations (Sperber, 1975; Bloch, 2004; Whitehouse, 2004). Learning a technical procedure requires an understanding of both ultimate intentions and the proximate intentions that lie behind sequential chains of action-units. However, in ritual actions, proximate and ultimate intentions are de-coupled (Sorensen, 2007).

De-coupling representations of proximate and ultimate intention is essential because it undergirds the focal difference between imitative and emulative behavior. Gergely, Bekkering, and Király (2002) further note that emulative teleological learning operates according to the principle of rational action, where even the proximate intentions associated with action-units are causally linked to the pursuit of a particular ultimate intention, whereas imitative learning entails teleologically opaque or 'ritualized' procedural sequences in which a string of actions and the proximate intentions necessary to generate them is not causally linked to the pursuit of a given ultimate intention. In a series of experiments, Gergely et al. (2002) have documented an early emerging bias towards imitative learning ("copying" of chunks of behavior) when pedagogical cues are present and emulative learning (based on reconstructing the causal relationship between actions and intended outcomes) when such cues are unavailable (see also Southgate, Chevallier, & Csibra, 2009). Some experimental evidence suggests that ostensive cuing implicitly triggers in infants as young as 8 months expectations that the information imparted will be useful in future situations (Csibra & Gergely, 2009). One possibility is that all ostensively cued behavior is assumed by default to have a physical-causal rationale, known to somebody if not to oneself (Lyons et al., 2007). Another possibility is that such behavior is assumed by default to be a matter of stipulation and convention, carrying normative force. For example, 3-year olds and, to a lesser degree, even younger children show strong reactions (e.g., protest, corrections) to violations of newly learned arbitrary rules (Rakoczy, Warneken, & Tomasello, 2008). This intriguing research suggests that the capacity to take an imitative 'ritual stance' appears very early in development. New research on this topic has examined the process by which children come to recognize that in some cases imitative actions can be informed by teleological reasoning (and thus understood as a technical action) whereas other times they cannot (and thus should be understood as a ritualized action).

Theory of living kinds

The importance of domain-specific theories can also be seen in how we categorize and reason about the biological world. One striking aspect of human concepts of living things is that they are organized into multi-level hierarchical inclusion systems (e.g., animals, birds, sparrows, white-crowned sparrows), where a "basic" or middle level of abstraction (e.g., either birds or sparrows, depending on one's level of expertise; Tanaka & Taylor, 1991) is accessed most quickly on a range of cognitive tasks (Rosch, 1978). These taxonomies are found broadly across different communities and contexts (Berlin, Breedlove, & Raven, 1973), and basic-level categories serve as the basis for generalizing knowledge (e.g., upon learning that one bird has a particular feature, children and adults alike tend to extend the new fact to another bird, even if it looks very different; Gelman & Markman, 1986).

The extent to which concepts of living things can be considered biological, however, depends on age, cultural context, and instruction. As with theory of mind, we see both early sensitivity and extensive conceptual change. Even infants distinguish animate patterns of motion from inanimate patterns of motion on the basis of perceptual cues from point-light displays (Bertenthal, Proffitt, Spetner, & Thomas, 1985), anticipate different causal consequences when animate vs. inanimate objects collide (Spelke, Phillips, & Woodward, 1995), and expect animate objects—but not inanimate objects—to move directly toward goals (Rakison, Cicchino, & Hahn, 2007; see Opfer & Gelman, 2010, for review). By preschool age young children believe that living things engage in distinctively self-generated and regular patterns of behavior and growth (Bulloch & Opfer, 2009; Inagaki & Hatano, 2002; Massey & R. Gelman, 1988; Opfer, 2002; Rosengren, Gelman, Kalish, & McCormick, 1991; Barrett, Todd, Miller, & Blythe, 2005). They treat membership in an animal category as absolute, and distinctions between different animal species as natural and objective, whereas they view distinctions between different artifact species as conventional and subjective (Rhodes & Gelman, 2009a, 2009b).

Yet there is also massive conceptual change regarding the classification of biological items: it can take children years to sort out which things are alive (Carey, 1985), or to appreciate that humans are one kind of animal among many (Johnson, Mervis, & Boster, 1992). At the same time, beliefs concerning basic biological concepts, including mechanisms of biological transmission (e.g., inheritance, ingestion), vary widely as a function of cultural input and instruction (e.g., Au, Chan, Chan, Cheung, Ho, & Ip, 2008; Herrmann, Waxman, & Medin, 2010; Medin, Waxman, Woodring, & Washinawatok, 2010).

Contamination and illness are particularly informative for exploring children's causal understandings, because biological reasoning often requires the recruitment of unobservable entities and processes (such as germs or toxins) to predict and explain more overt phenomena (Legare, Wellman, & Gelman, 2009). Lay contamination understanding exemplifies this sort of reasoning: adults report that contact with a contaminating substance causes food or beverage to become undesirable and offensive (Rozin & Fallon, 1987), even if the contaminating substance is not toxic and leaves only an imperceptible physical or symbolic trace. Thus, contamination provides a forum where children can potentially provide rich biological explanations based on unobservable as well as observable causal factors. Further, naïve biological reasoning about contamination provides a fruitful domain for exploring cultural differences. Although the specific kind of substance, process, or contact considered contaminating varies across different cultural contexts (Stigler, Shweder, & Herdt, 1990), sensitivity to contamination is likely universal (Hejmadi, Rozin, & Siegal, 2004; Raman & Gelman, 2004; Rozin, Fallon, & Augustoni-Ziskind, 1985). Similarly, illness is a human universal, although the ways in which particular cultural communities explain, treat, and prevent ill health is deeply shaped by their worldview, particular belief systems, and valued cultural activities (Inagaki & Hatano, 2002; Rozin, 1996).

One open question is whether there are certain modes of thought that are used preferentially when reasoning about biological concepts (Keil, 1995). Two that have been proposed are psychological essentialism and teleological thinking. Psychological essentialism is an implicit belief that members of a category share deep commonalities that make them what they are (Ahn et al., 2001; Gelman, 2003; Medin, 1989). In other words, categories have a deeper reality underlying manifest appearances. Thus, although birds are widely varying in size, behavior, habitat (consider hummingbirds, dodos, penguins, and vultures), they all share an underlying “bird essence”. Essentialist accounts have been offered, in one form or another, for thousands of years, extending back at least to Aristotle and Plato. Research with young children suggests that essentialism is an early cognitive bias, as young children's concepts reflect a deep commitment to essentialism. Children look beyond the obvious in many converging ways: when learning words, generalizing knowledge to new category members, reasoning about the insides of things, contemplating the role of nature versus nurture, and constructing causal explanations. For example, when asked to consider a newborn calf that is raised exclusively with pigs, young children predict that it will grow up to moo and have a straight tail – that nature will overcome nurture (Gelman & Wellman, 1991). These findings argue against the standard view of children as concrete or focused on the obvious (Piaget, 1928), instead claiming that children have an early, powerful tendency to search for hidden, non-obvious features of things. For cross-cultural evidence for essentialism, see: Astuti, Solomon, and Carey (2004); Atran, Medin, Lynch, Vapnarsky, Ucan Ek', and Sousa (2001); Diesendruck (2001); Gil-White (2001); Sousa, Atran, and Medin (2002); Waxman, Medin, and Ross (2007).

Some have suggested that psychological essentialism is rooted in an intuitive biology (Atran, 1998; Boyer, 2001). Just as humans universally construct basic-level categories and taxonomies, so too do they honor the principle that dissimilar items are deeply alike and can share a name. On the other hand, psychological essentialism appears to be a more general way of thinking that transcends domains (Bloom, 2000; Gelman & Hirschfeld, 1999). For example, essentialist beliefs extend to reasoning about individuals and not just biological kinds (e.g., transplants; soul; Gottfried, Gelman, & Schultz, 1999). Essentialism also appears to encompass everyday objects, where for example, people report not wanting to wear a sweater once owned by Hitler (Nemeroff & Rozin, 1994), and people will pay vast sums for Neil Armstrong's autograph or a Picasso original (Bloom, 1996). Children, too, place special value on objects with strong emotional ties (Frazier & Gelman, 2009; Frazier, Gelman, Wilson, & Hood, 2009; Gelman & Frazier, 2007; Hood & Bloom, 2008). Even humble artifacts (an ordinary spoon) can be thought of in terms of an essence, namely, the intent of the creator can be decisive in determining category membership (Gelman & Bloom, 2000). Finally, psychological essentialism also extends to reasoning about social kinds (Hirschfeld, 1996; Rothbart & Taylor, 1992; Rhodes & Gelman, 2009; Birnbaum, Deeb, Segall, Ben-Eliyahu, & Diesendruck, 2010; Diesendruck & haLevi, 2006). An open question is the extent to which psychological essentialism starts out specifically for the biological domain, and then spreads, or is a more domain-general phenomenon from the start (Gelman, 2003).

Teleological reasoning involves seeing entities or parts of entities as existing for a purpose. For example, we might say that a teacup has a handle so that we can hold it without burning our fingers, or that giraffe has a long neck so that it can eat leaves off tall trees. An ongoing debate concerns whether this tendency to seek purpose in the world around us is specific to certain domains, such as biological kinds and human-made artifacts (Keil, 1992) or instead reflects a broad teleological tendency (Kelemen, 1999). Evidence for the latter is that children tend to engage in “promiscuous teleology” (reporting that clouds are made for raining, or lions are made for going in a zoo), and adults tend to fall back on teleological explanations when placed under timing constraints and forced to answer quickly (Kelemen & Rosset, 2009). Kelemen suggests that children may extend this tendency to reason about existential questions such as the origins of life, and ultimately result in an intuitive theology (with everything having a designer and a purpose).

Both psychological essentialism and teleological reasoning have implications for acceptance of evolutionary theory. There is extensive resistance to evolutionary theory (upwards of 50% in the U.S.), and conceptual biases--including essentialism and promiscuous teleology--play an important role (Sinatra, Brem, & Evans, 2008; Gelman, 2003; Kelemen, 2004; Mayr, 1982; Shtulman & Schulz, 2008). Gelman and Rhodes (in press) suggest that essentialism poses five obstacles to a theory of evolution: (a) Essentialism assumes that categories are stable and immutable, which competes with the view from natural selection that species can change over generations. (b) Essentialism posits that category boundaries are relatively strict and impermeable, thus leading to a rejection of categories that cross strict boundaries. (c) Essentialism leads to an underestimation of category variability, or treating variability as “noise”, thereby leading to difficulty accepting the core factual basis for evolution. (d)

Essentialism assumes that causes inhere in the individual, leading to difficulty appreciating population-level causal forces (which are at play during evolution). (e) Finally, the Platonic notion of category ideals encourages the view of evolution as progressive (with species always improving), which mischaracterizes the nature of evolutionary change.

When theories collide: do explanatory frameworks co-exist or compete?

Natural and supernatural theories are alike in providing broad frameworks that attempt to uncover underlying explanatory principles to account for complex phenomena. Although much research has focused on causal explanatory reasoning in natural or scientific domains (see previous sections), until recently there has been much less psychological research on thinking about supernatural, magical, or divine powers (but see Astuti & Harris, 2008; Barrett, Richert & Driesenga, 2001; Boyer & Walker, 2000; Legare & Gelman, 2008; Whitehouse & McCauley, 2005; Rosengren, Johnson, & Harris, 2000; Woolley, 2000). Given the shared objectives of natural and supernatural cognition – to enable us to explain, understand, and intervene in the world – there is much to be gained by investigating the extent to which a single cognitive system accommodates both kinds of thinking, even with respect to the same phenomenon.

In spite of the fact that access to both kinds of explanatory systems is a universal psychological experience, little is known about how children and adults respond to distinct natural and supernatural explanatory accounts of the world around them, how such beliefs co-develop, or the extent to which people accommodate both to explain the same events. In both lay and scientific writing, natural (or scientific) explanations and supernatural (or religious) explanations are often presented as competing or incompatible (Bloom, 1992; Dawkins, 2006; Preston & Epley, 2009). The assumption that scientific explanations may eventually prevail due to their superiority at providing empirically testable explanations is consistent with the Secularization Hypothesis, which states that as science and technology advance they will increasingly displace religious explanations (Norris & Inglehart, 2004). An alternative to this displacement account is that natural and supernatural explanations do not overlap because they serve different objectives or are used to explain different types of events (Biema, 2006; Gould, 1997).

Contrary to claims of either displacement or non-overlap, we argue that the commonly held assumption that science and religion offer incompatible, competing frameworks is inaccurate at the psychological level. New cognitive developmental research from a variety of different cultural contexts indicates that these two explanatory frameworks often coexist within the same individual, even with respect to the same to-be-explained phenomenon. We review evidence that scientific and supernatural explanatory systems co-exist, both across development and across diverse cultural contexts (Astuti, Solomon, & Carey, 2004; Evans, Legare, & Rosengren, 2011; Raman & Gelman, 2004). For example, with regard to human origins, Americans and Europeans are exposed both to a creationist explanation (i.e., God placed humans on earth) and an evolutionary explanation (i.e., humans evolved from different kinds of living things) (Evans, 2001). Similarly, both biological and supernatural explanations for the transmission and cure of serious illnesses are prevalent cross-culturally. For instance, although information about the transmission of the AIDS virus is widely available via health and education programs (Legare & Gelman, 2009), supernatural accounts of infection based on witchcraft are promulgated (Ashforth, 2001; Farmer, 1999; Legare & Gelman, 2008). Finally, although all people are confronted by the biological inevitability and finality of death, in many religious traditions they are also exposed to afterlife beliefs (Astuti & Harris, 2008; Harris & Giménez, 2005; Talwar, Schleifer, & Harris, in press).

This research adopts a different stance from long traditions of theory and research in developmental and cultural psychology. In developmental psychology, it has been claimed that young children gradually abandon a belief in supernatural causation and instead acquire a more objective, rational, or scientific appreciation of the world around them (Harris, 2009; Piaget, 1928). Likewise, in cultural psychology, research has shown that education and modernization accelerate various aspects of cognitive development (Cole, 2005; Gauvain & Munroe, 2009; Luria, 1976; Vygotsky, 1978). Thus research in each of these disciplines is consistent with the possibility that, over the course of history, with more widespread access to education and modernization, a focus on natural explanations will increasingly compete with, and even displace, supernatural explanations. However, relatively few adults, across a wide range of cultural backgrounds, endorse exclusively natural explanations (Hood, 2009; Misztal & Shupe, 1992; Raman & Winer, 2004; Tambiah, 1990). How can the traditional view of cognitive development as the acquisition of more objective, rational, and scientific thought be reconciled with the fact that supernatural explanations are present in many cultural contexts and are a pervasive feature of cognition for most adults?

One plausible explanation for this paradox could be that these distinct explanatory frameworks operate differently in different individuals (i.e., some individuals are more scientific or religious than others) or at least over different domains or contexts (i.e., an individual may hold scientific explanations for certain phenomena, and supernatural explanations for other phenomena). However, new research has demonstrated that both natural and supernatural explanations frequently operate within the same mind to explain the very same event or phenomenon (Legare, Evans, Rosengen, & Harris, 2011). In fact, in certain domains, the tendency to invoke supernatural explanations increases with age rather than decreases (Astuti & Harris, 2008; Evans, 2001; Harris & Giménez, 2005; Legare & Gelman, 2008; Raman & Gelman, 2004). Consistent with socio-cultural perspectives on development (Cole, 2005; Greenfield, Suzuki, & Rothstein-Fisch, 2006; Rogoff, 2003; Vygotsky, 1978), we propose that the development of both natural and supernatural explanatory systems requires a considerable amount of cultural experience and participation in dynamic aspects of the social learning process, in which children seek and actively construct information in collaboration with others (Callanan, 2006). Consequently, both natural and supernatural explanations can operate within the same mind (Subbotsky, 2001), for the same to-be-explained phenomena.

Psychological research on explanatory coexistence has demonstrated that in response to a question about a single event or object of explanation, individuals recruit different explanatory frameworks in several ways (Evans, Legare, & Rosengren, 2011). In the case of target-dependent thinking, natural and supernatural domains remain alternative views of the world that are both recruited in order to provide a coherent explanation of a given phenomenon but are used to explain distinct aspects of that phenomenon, depending on the particular kind of causal attribution. For example, in the case of reasoning about the origin of diverse species, an evolutionary framework might be recruited to explain the origin of non-human species whereas a theistic framework might be recruited to explain the creation of human beings.

In the case of synthetic thinking, natural and supernatural explanations are both used to explain the same aspects of a given phenomenon. Such dual explanations may involve a loose integration of natural and supernatural frameworks but without any detailed consideration of how they would interact (Vosniadou, Vamvakoussi, & Skopeliti, 2008). For example, when reasoning about death, one might recruit information about both the body and the soul (Harris & Giménez, 2005) without specifying the role each played in the process.

In the case of integrated thinking, natural and supernatural explanations for a single phenomenon are combined in a more precise and well-coordinated manner. Integration is achieved by using natural and supernatural explanations for different levels of analysis; a natural cause can be regarded as proximate, and a supernatural cause as ultimate. For example, in the case of serious illness, a biological risk factor may be regarded as a proximate cause whereas supernatural punishment may be regarded as the ultimate cause (Legare & Gelman, 2008).

We argue that supernatural explanations do not always appear early in development, nor are they primitive or immature ways of thinking that are suppressed over the course of development. Instead, like natural explanations, they are a pervasive feature of human cognition across the lifespan, are constructed and elaborated through socialization and cultural learning and may be founded on earlier intuitive explanations.

Summary and conclusions

The study of mental content is daunting in light of its seemingly unconstrained variety. However, empirical investigations of the mind reveal systematic patterns in the ways that humans consider evidence and build knowledge structures. In brief, an examination of mental representations supports three broad conclusions. First, concepts are informed by domain-specific, causal-explanatory theories and not solely constructed bottom-up from a perceptual basis. Second, there are persistent cognitive biases that influence what information we take in and consider. Third, multiple, seemingly incompatible theories co-exist, side-by-side, within an individual. Many questions remain for the future, including: the evolutionary basis of intuitive theories; what sorts of social contexts and cultural practices influence or alter intuitive theories; what conditions foster conceptual variation and conceptual change; how intuitive beliefs relate to explicit cultural stories (see Astuti, Solomon, & Carey, 2004, for an example of intuitive theories that do not always conform to explicit cultural descriptions); and the influence of particular intuitive theories for human behavior (e.g., effects of theory of mind on cooperative and competitive interactions; effects of psychological essentialism on treatment of social groups). As we have attempted to show in this chapter, developmental evidence from infants and young children can be particularly valuable by revealing the process by which knowledge and beliefs are constructed.

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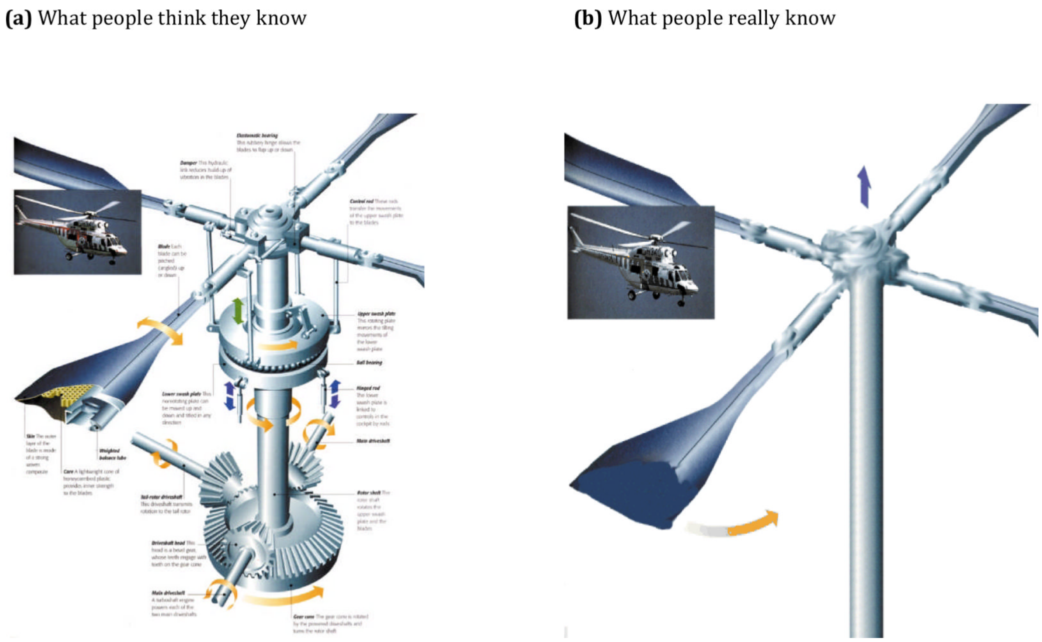

Fig. 1.

When people estimate how deeply they understand the workings of various systems, they tend to think they know for more depth of detail than they actually do. When asked how a helicopter works, they seem to think they have knowledge approximating a detailed annotated drawing, but actually have a much coarser understanding corresponding to little more than the sense of a thing with blades that turn and provide lift. This illusion is quite specific to explanatory kinds of knowledge. People estimate the depth of their knowledge of procedures, facts and narratives much more accurately. From Keil (2003). Adapted with permission from [51]. Wright, M., Patel, M. eds (2000) How Things Work Today, Crown Publishers, New York

Table 1

Examples of coexistence thinking across three domains of biological thought. Taken from Legare, Evans, Rosengren, & Harris, under review.

Label	Definition	Origins	Illness	Death
Target-dependent thinking	Two different explanations remain alternative views of the world, recruited to explain distinct aspects of a given phenomenon, depending on the target or context	“Man is created with a soul, which makes him different from an animal--that can be found in the book of Genesis. And um, so I would consider a monkey an animal without an eternal soul...“ (Evans et al., 2010)	“Witchcraft can cause a disease that looks like AIDS” (Legare & Gelman,2008)	“Because if she is with God I guess she could see and hear. Her soul is alive even if her body is buried” (Harris & Giménez, 2005)
Synthetic thinking	Two different explanations are combined into a single explanation without explicit integration	“Well, again, evolution with the environment, but I am also a religious person, so that's a difficult question. I think a bit of both perhaps...” (Evans, et al., 2010)	“It might be witchcraft and having unprotected sex” (Legare & Gelman, 2008)	“Even if she doesn't use her heart, up in Heaven there is something special that makes the rest of your body work; it is like magic” (Harris & Gimenez, 2005)
Integrative thinking	Two different explanations are integrated into a single explanation	“[Humans] got here from gorillas and monkeys, cause they're intelligent creatures if you really look at them... The first monkeys probably evolved from something else or got put here as an individual... God could have put them [the monkeys] here” (Evans, 2000)	“A witch can put you in the way of viruses and germs” (Legare & Gelman, 2008)	“If she is in Heaven she will be with other people and she will communicate with them. It is as if you are brought back to life because God bring you back to life to be with him” (Harris & Gimenez, 2005)