Young Children's Conception of the Biological World

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ABSTRACT—*What are the components of children's biological-knowledge system before systematic teaching at school? Can this knowledge system be called naive biology? We propose that young children's biological-knowledge system has at least two essential components—(a) the knowledge needed to identify biological entities and phenomena and (b) teleological and vitalistic causality—and that these components constitute a form of biology. We discuss how this naive biology serves as the basis for performance and learning in socially and culturally important practices, such as health practices and biology instruction.*

KEYWORDS—*naive biology; living–nonliving distinction; teleology; vitalism; illness causality*

Do young children distinguish living entities (i.e., animals and plants) from nonliving things, and biological phenomena (e.g., internal bodily processes, illnesses) from physical and mental ones? Can they make predictions and give causal explanations in a "biological" fashion? In short, have they acquired an understanding of biology that is distinct from their understanding of physics and psychology? Children's biological understanding has become an increasingly popular subject in the study of conceptual development (Wellman & Gelman, 1998) since Carey (1985) revived interest in Piaget's early notion of animism and fueled debates concerning the above questions. Carey claimed that young children's reasoning about biological phenomena is animistic and personifying because children lack domain-specific knowledge in biology, not because of domain-general intellectual immaturity, as Piaget claimed. However, like Piaget, she asserted that, before about age 10, children make predictions about and explain biological phenomena based on intuitive psychology (i.e., intentional causality); children consider that bodily processes and properties are under human intentional control.

The general consensus arising from studies in recent decades is that children as young as 5 years—much younger than Carey claimed—possess a theory-like knowledge system that can be called *naive biology*, which involves a set of causal devices enabling children to offer coherent predictions and explanations for biological phenomena.

In this article, we present evidence that young children possess naive biology, and we discuss how this naive biology serves as the basis for performance and learning in culturally and socially important practices.

YOUNG CHILDREN POSSESS THE KNOWLEDGE NEEDED TO SPECIFY TARGETS OF BIOLOGY

To infer that children possess a naive theory of biology rather than piecemeal knowledge of biological phenomena, their knowledge system must be shown to have at least two demonstrable components: (a) the living–nonliving and mind–body distinctions and (b) a set of causal devices (internal mechanisms enabling causal reasoning) for biological phenomena. These components are essential in that adults' (scientific) theory of biology shares them, although children's understanding of biology is different from that of adults. With regard to the first component, studies to date indicate that young children have the knowledge needed to identify biological entities and phenomena. Even infants can discriminate between human actions and the motions of inanimate objects in terms of a distinction between self-initiated movements and those caused by external force. Preschool children correctly judge whether unfamiliar animals and artifacts can generate self-initiated movements and give different causal explanations for different entities' movements (Gelman, 1990).

Although plants do not reveal self-generated movements, recent studies using sophisticated methods show that preschoolers recognize plants as distinct from nonliving things in some respects, such as growth or regrowth (i.e., when damaged, both animals and plants can regrow, whereas artifacts can be mended

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only by human intervention). When directed to compare animals and plants by analogy, 5-year-olds explicitly recognized commonalities between animals and plants in terms of their need for food and water and justified their responses by mapping food for animals to water for plants (Inagaki & Hatano, 2002).

Moreover, young children draw analogically on their knowledge about humans when attributing properties to less familiar living entities or predicting those entities' reactions to novel situations; e.g., children often justified their predictions about other entities by referring to humans (using phrases such as "like people do"; Inagaki & Hatano, 2002). Children do this because they possess fairly rich knowledge about humans compared with their knowledge about other animals and plants, and they apply this knowledge in a constrained way so that they can generate "educated guesses" for entities' behaviors in novel situations. This human-based inference, or person analogy, is useful in everyday biological problem solving and understanding, because humans share biological properties and processes with other living things. In other words, in contrast with the earlier views that saw it as an immature thought process or as a psychologically distorted understanding of biological phenomena, the animistic or personifying tendency can be viewed positively, as reflecting a child's active and adaptive mind.

Children can also distinguish bodily from mental functions, or biological phenomena from psychological ones. Kalish (1997) found that preschool children distinguish between bodily and mental reactions to contamination in that they recognize that eating contaminated food is likely to make one sick whereas knowing that one has eaten the contaminated food often induces emotional (mental) responses. Schult and Wellman (1997), focusing on human actions that are caused not only by psychological forces (e.g., desires) but also by physical forces (e.g., gravity) or biological processes (e.g., fatigue), revealed that 4-year-olds can give different causal explanations for three kinds of human actions—mistakes, physically impossible actions (e.g., floating in the air), and biological impossible actions (e.g., stopping growth).

YOUNG CHILDREN APPLY NONINTENTIONAL CAUSALITY TO BIOLOGICAL PHENOMENA

The second essential component of a theory of biology is a set of causal devices. Carey (1985) claimed that young children base their explanations of biological phenomena on intentional causality because they are ignorant of the physiological mechanisms involved. However, recent research has revealed that children can draw on causal devices that are biological in nature in that they are not physiological but are also nonintentional—among others, *life teleology* and *vital power*—and that young children rely on these causal devices in understanding biological phenomena only. (Biological essentialism, a belief that only animals and plants possess the underlying essence that is inherited and gives rise to a set of their characteristic features, may be another such device, but we will not discuss it in this paper.)

Teleology is a general view that any enduring property of an entity has some functions for it or for other related entities, and the version called life teleology is applied to parts or properties of the biological kind—e.g., the idea that bodily organs exist to sustain life (Keil, 1992). Causality in terms of vital power assumes that bodily processes (e.g., workings of the body parts) are meant to sustain life by taking in and exchanging vital force, which can be conceptualized as unspecified substance, energy, or information (Inagaki and Hatano, 2002). These two causal devices are compensatory in their primary application to biological phenomena and constitute a teleo-vitalistic assumption as a biological causal framework: Bodily properties, functions, and processes exist and operate for maintaining life.

Keil (1992) indicated that when presented with pairs of teleological explanations (e.g., plants are green "because it is better for plants to be green and it helps there be more plants") and mechanical explanations ("there are little tiny parts in plants that when mixed together give them a green color"), 5- to 7-year-olds strongly preferred teleological explanations for biological kinds and mechanical explanations for nonbiological natural kinds (e.g., why emeralds are green).

Inagaki and Hatano (2002) showed that, when asked to choose either an intentional, vitalistic, or physiological causal explanation for a bodily phenomenon such as digestion or respiration, 6-year-olds chose vitalistic explanations as most plausible most often. For example, when given the question, "Why do we eat every day?" the children preferred a vitalistic explanation ("Because our stomach takes in vital power from the food") to either an intentional explanation ("Because we want to eat tasty food") or a physiological explanation ("Because we take food into our body after its form is changed in the stomach and bowels"). The preference for vitalistic explanations was observed among not only Japanese children but also Australian and American children.

When asked to predict and explain eating and related phenomena (e.g., living long or susceptibility to illness) in some hypothetical novel situations, a considerable portion of 6-year-olds could generate vitalistic explanations, such as "Probably the grandpa eating a lot will live until 100 or 200 years old. 'Cause power comes out from eating food." These children tended to consider that energy or power taken in through eating would help people live long, resist falling ill, and recover quickly from sickness or even injury (Inagaki & Hatano, 2002).

Slaughter and Lyons (2003) found that young children who spontaneously drew on the teleo-vitalistic assumption (specifically, referring to life as a goal) in reasoning about human body functions showed a more sophisticated understanding of death, acknowledging that death is only applicable to living things and that death is caused by breakdown of bodily functioning. Moreover, when explicitly taught this assumption, 4-year-olds showed significant development in their understanding of death, which had not been mentioned in the course of training, as well as in their understanding of human body functions. The authors suggest that the acquisition of the teleo-vitalistic assumption of the human body helps children reformulate the concept of death.

Based on the above findings and others, we can conclude that young children before schooling have an understanding of biology separate from their understanding of psychology. This early acquisition of naive biology is not surprising from an evolutionary perspective; the survival of early humans required some knowledge about animals and plants as potential foods, as well as knowledge about bodily functions and health to protect themselves. Some developmentalists (e.g., Gelman, 1990) assert that children are predisposed, prior to much experience, to pay attention to particular aspects of the environment (e.g., an entity's movement) and to entertain particular interpretations of their observations (e.g., bodily ailment caused by unfamiliar food), helping them to acquire naive biology early.

APPLICATIONS OF RESEARCH ON NAIVE BIOLOGY TO PRACTICAL ISSUES

Children's naive biology is not only interesting in itself but is also significant as the basis for children's performance and learning in socioculturally important practices. As examples, we will address the applications of research on naive biology to health practices and biology instruction.

Children Engage in Health Practices With Biological Understanding

First, we point out that research on naive biology contributes to specifying at what point young children engage in practices for maintaining health (e.g., avoiding contagion, attending to diet) with biological understanding, not simply because they have been asked by their parents to do so. Increased interest in naive biology has prompted research on children's understanding of illness. Most studies focus on children's understanding of germs as causes of illness. A tentative conclusion from these studies is as follows (see Siegal & Peterson, 1999): Young children do not understand germs as part of a uniquely biological process through which people fall ill, though they recognize that germs are something that makes one sick. Even older, school-aged children can learn the role of germs in getting ill only through systematic and intensive instruction. This conclusion seems plausible, given that germs were discovered to cause illness only as recently as the 19th century.

However, it is unlikely that children have no biological knowledge about causes of illness before instruction, because preventing illness was important for the survival of humans long before germ theory was introduced. Keil, Levin, Richman, and Gutheil (1999) point out that ancient people (represented by Hippocrates of Greece) and people from traditional cultures possessed folk theories of medicine that were biological in nature; one of these is the imbalance theory, which interprets disease as being caused by an imbalance of a person's humors or other bodily constituents. The vitalistic conception of illness, a variant of the imbalance theory, continues to exist in Oriental culture as an interpretation for susceptibility to illness. Because young children have some biological understanding of bodily functions based on vitalistic causality, it seems plausible that they could have a substantial understanding of illness phenomena from this vitalistic perspective.

Inagaki and Hatano (2002) found that young Japanese children recognize that susceptibility to illness, which varies depending on daily activities, is a critical factor in health and sickness. Children aged 4 to 6 years were presented with two protagonists, who were allegedly different in terms of biological/physical factors (e.g., imbalanced diet) or psychological/moral factors (e.g., misbehaviors) in their daily activities, and asked which of the two was more likely to catch a cold when both had contact with a sick person. Most of the children recognized that the physical aspects of daily activities would affect susceptibility to illness. Although they believed that psychological factors would also contribute, when forced to choose between the two factors, the children considered biological factors to be more important than psychological ones in resisting illness (Fig. 1).

Moreover, in another study we found that the effect of the physical aspects of daily activities on illness susceptibility was explained more often in terms of vital power than in terms of those aspects' social/moral desirability (Inagaki & Hatano, 2005). Here, 6-year-olds were presented with two protagonists, one of whom engaged in a bad biological/physical practice (e.g., eating few vegetables) and caught cold and another who engaged in a good practice and did not catch cold; the children were asked to choose between two justifications for having/not having caught cold. They chose justifications that referred to vital power ("Power doesn't come out from eating few vegetables, so he couldn't turn germs away") significantly more often than they chose justifications referring to moral aspects of the behavior (e.g., disobeying the mother's request). These findings strongly suggest that biological understanding can be used even from an early age to encourage children to engage in health-maintaining practices.

Children Learn Advanced Biological Notions Based on Naive Biology

Second, we emphasize that studies of naive biology provide science educators with empirical bases for designing instruction. When children are taught at school about basic concepts of scientific biology, they tend to incorporate those concepts into their naive biological framework. This has both positive and negative effects on learning scientific concepts. For example, because children who possess naive biology tend to rely on the person analogy for not only animals but also plants, they can readily acquire the integrated category of animals and plants, understood as being similar to humans in their ways of life. However, children cannot readily understand the essential difference between animals and plants (i.e., plants can produce

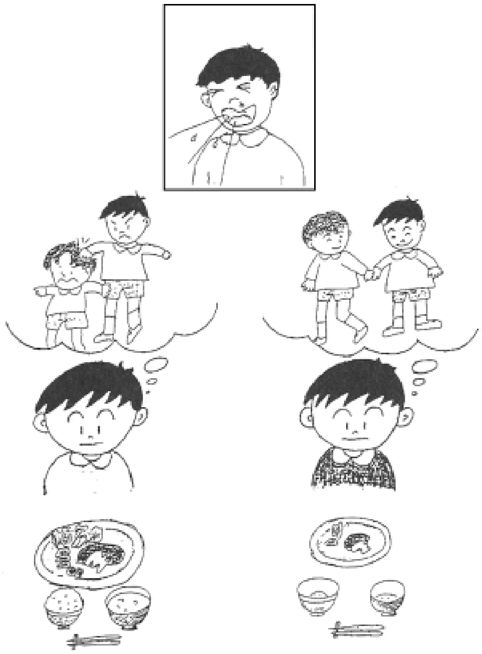

Fig. 1. Example of a stimulus card used in a study of children's understanding of susceptibility to illness. Participants were asked, ''When playing with a child who has a cold and is coughing a lot, who is more likely to catch cold—boy A, who often hits and pinches his friend on the back but eats a lot at meals every day, or boy B, who is a good friend but eats only a little?'' For this type of question, most 5-year-olds chose boy B, weighting the biological/physical cue (e.g., insufficient nutriments) more heavily than the psychological/moral cue (e.g., misbehavior). From *Young Children's Naive Thinking About the Biological World*, by K. Inagaki & G. Hatano, 2002, New York: Psychology Press, p. 91. Copyright 2002, Routledge/Taylor & Francis Group, LLC. Reproduced with permission.

nutriments themselves), accepting the false mapping of water for plants to food for animals. Thus, they often fail to recognize the significance of photosynthesis.

The same can be said about ideas of evolution. Because naive biology involving teleo-vitalism assumes that living things maintain life by adjusting themselves to their ecological niche, children are ready to accept any biological entity's gradual adaptive changes over generations, and thus are ready to form something close to the Lamarckian idea of evolution. In contrast, the Darwinian idea of evolution must be very hard to grasp.

In fact, in a study in progress, Inagaki and Hatano found that Japanese fifth graders interpret the learned fact that animals have changed in their natural history both within and between species as being due to dynamic adaptation, not mutation and natural selection. These children often believe that humans evolved from monkeys (macaques), which may reflect a culturally shared belief in Japan, which has wild macaques. Evans (2000) found that questions about species adaptation or microevolution evoked Lamarckian-type explanations in American upper-elementary-school children. Interestingly, questions about the origins of new species elicited creationist explanations. These discrepant results suggest that even children's biology is affected by religious and other cultural beliefs.

FUTURE ISSUES

We can now draw a rough sketch of what young children's naive biology is like. Future research will focus on how naive biology emerges, develops, and changes in various ecological and cultural settings. Such studies will extend our current knowledge, which is based on data collected primarily from children and lay adults living in highly technological, civilized societies that are dominated by western medicine, etc. (e.g., Medin and Atran, 2004), and will enrich our knowledge about the human mind. It will also be important to examine the processes by which a child's naive biology evolves into an adult's biology. What conditions are likely to induce this qualitative change from the child's biology to the adult's? Are the constituents of a child's biology (e.g., vitalistic causality) completely replaced by those of adult biology (e.g., physiological causality), or do they still exist with decreased salience? Many interesting issues await examination in the coming decade.

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