Representation, Memory, and Development

Essays in Honor of Jean Mandler

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On Animates and Other Worldly Things

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Jean Mandler made fundamental contributions to our understanding of the origin and development of concepts. These include her elegant theoretical and experimental work on scripts and schemas, memory, representation, and infant cognition. Her theoretical articles about "how to make a baby" are classics.

Mandler started her developmental work relatively late in her scientific career, having focused initially on animal learning. I had the good fortune to be an undergraduate at the University of Toronto, where Jean Mandler had an animal lab. So, I learned firsthand that, from the beginning, she was pondering the roles of attention and concepts. This was not exactly the "in" thing to do at the time. Behaviorism reigned and talk about mental matters was viewed as unscientific by almost everyone. No matter, Jean always was open to the idea that nonlinguistic or prelinguistic individuals might be able to think. Amazingly, a considerable number of students of early cognitive development still reject this possibility. Journals and meetings are full of efforts to explain away the converging lines of evidence. This is especially puzzling in Jean's case. She did not start out with the idea that infants use general

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categories. Instead, she moved toward it because she allows her data to speak to her and because she is careful to design studies that offer an opportunity to consider different theories. Jean is a scientist's scientist; she does exquisite, careful, replicable research.

If anything, one might argue that Mandler's interpretation of her data is on the conservative side. Not only are the infants and toddlers in the experiments using general categories, they are doing so with representations—small, toy replicas—of real-world objects. Converging evidence from the object-manipulation, sequential-touching, and generalized imitation tasks, show that these very young children place replicas of animals, vehicles, and so forth, into separate categories. This is one reason I am motivated to push Mandler's proposal about the origins of these categories even more on the conceptual side than she has. It is not that I want to rule out her idea that infants use information from different kinds of motion path schema (Mandler, in press). I do so because I am concerned that, by themselves, such schema do not form a sufficient base from which to achieve the target inductions.

ANIMATE VERSUS INANIMATE OR ANIMAL—NOT ANIMAL?

Mandler has concluded that infants' global concept of animal is embedded in a domain-general, *Animal—not Animal* conceptual structure and that "the distinction is easily learnable from the spatial and movement information presented by the visual system" (Mandler, in press). I agree that infants use global concepts. However, I prefer to say that the origin and development of the animate–inanimate distinction benefits from skeletal, domain-specific causal structures that apply to objects that are separably moveable as a whole. Causal principles that apply to different categories of separably moveable kinds of things in the world facilitate fast learning about the domain-relevant features, attributes, and predicates about global categories (e.g., Gelman, 1990; Gelman, Durgin, & Kaufman, 1995; Gelman, Spelke, & Meck, 1983; Williams, 2000; Keil, Kim & Greif, in press; Williams & Gelman, 1998). Plants, being attached to the ground, are clearly outside the range of items with which we have been dealing. As it turns out, so too are sentient and seemingly self-moving machines.

There is no question that various perceptual characteristics of trajectories, of animate and inanimate objects, can influence decisions about their identity. It is one thing, however, to grant that such perceptual information is relevant, and another to say that it forms the basis of the abstraction of the global, conceptual categories *animal* and *nonanimal*. There are reasons for my skepticism about the proposal that motion schemas of different kinds serve this function. First, although the per-

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ceptual system responds differentially to biological motion as opposed to nonbiological motion, there is no guarantee that such information is abstracted upward, that is, to the conceptual level. The visual system also responds differentially to color and represents spectral information in a three-dimensional color space. However, the dimensionality of the color space does not organize the everyday conception of colors. Similarly, we can move around in the world without bumping into objects, but we have a hard time accessing the implicit physics that our perceptual-motor system uses (Bransford, Brown, & Cocking, 1999; McCloskey, 1983).

Second, there is the problem of stimulus indeterminacy, a problem that has contributed significantly to my move to say that the issue of relevance is informed by conceptual as well as perceptual matters (e.g., Subrahmanyam & Gelman, in press; Gelman & Williams, 1998; Williams, 2000). Significantly, motion path information is neither necessary nor sufficient for the identification of animate and inanimate objects (Gelman et al., 1995; Williams, 2000). One way to demonstrate this point is to consider Stewart's theory (1982, 1984). She proposed that we perceive a novel moving object as inanimate when its motion path is consistent with Newtonian laws of motion. If the motion path violates Newtonian principles, then we perceive animacy and attributions like intentions, desires, hunger, affection, and so forth. In Gelman et al. (1995), we were able to present analyses of Stewart's own data and our follow-up studies that replicated and extended her findings. Repeatedly, we found that adults alter their interpretations of motion paths on the basis of causal considerations about the details of the motion paths they see to possible causal conditions.

CAUSAL INTERPRETATIONS OF MOTION

To obtain evidence for her theory, Stewart showed college student the trajectories of computer generated dots, each of which moved in ways that were either consistent or not with Newtonian mechanics. Gelman et al.'s (1995) additional analyses of Stewart's data, in combination with follow-up studies, yielded a number of results that represented departures from Stewart's predictions. For example, the perception of a path curving upward on the screen lent itself to a wide range of perspectives and causal interpretations, with some individuals attributing the path to an animate event and others attributing it to an inanimate event. Examples of answers included "... a bicyclist going around a corner"; "... a balloon and the wind was blowing and it went like this, this, like a helium balloon. It got caught up in the air"; "A horse climbing a mountain"; and "... some kind of magnetic ball that encountered a field that pushed it away."

The aforementioned descriptions are revealing on another level. They embed within them an account of how the "object" might have moved along the path in question. These "hows" were all about unseen causal factors that could support the way the object moved, including wind blowing, a horse climbing, and a magnetic ball in a field. These kinds of answers provide compelling evidence for our argument that the displays were fodder for causal principles, ones that encouraged interpretation of the motion paths in terms of the possible agents and conditions that generated the trajectories. What was perceived was interpreted with reference to the conditions that can cause the seen trajectory, even if this meant inventing invisible forces, mountains, or magnetic fields.

One might hold that the preceding argument applies to adults but not young children, who will not have learned enough to relate their perceptions to causally relevant considerations. If so, young children should be more likely than adults to rely on characteristic perceptual information when presented novel displays. This does not appear to be the case. If anything, 3- to 5-year-olds are more likely to "import" unseen or unheard information about energy sources. They do this when they decide whether a motion of an unidentified object was that of an animate or inanimate object moving in the dark, in a particular setting (Williams, 2000); a novel item shown in a photograph can move itself up and down a hill (Massey & Gelman, 1988); and when assigning predicates in either a picture or verbal task (Gelman & Subrahmanyam, in press).

Williams (2000) studied groups of adults and 3- and 4-year-olds' use of a sequence of motion paths for an object in a given context. The setting information for each trajectory was comprised of a still (frozen) clip from a video of a scene; for example, a high cliff dropping into a moving stream that had some trees along its banks. On some trials, there also was the sound of running water or a wind. Williams ended the presentation of a given context by rendering the screen completely dark. Then a pinpoint of light appeared somewhere on the screen. Pretest training encouraged people to think that the light was attached to a moving object in a darkened scene. For example, the light on the body of an object seemed to move along the top of the just-seen cliff, drop straight down from the cliff, smoothly or not, in silence or not. It also could be on an object that moved in, or just above the river, silently or not, and so on. After viewing a given motion path, participants were shown pairs of photographs, one each of an animate and an inanimate object (e.g., a duck and a leaf) and asked which one they had just watched move in the dark. Williams expected participants to choose inanimate objects when the just-seen motion paths were force-consistent with the natural setting they just saw. If the motion path was force-inconsistent for the given setting, he predicted they would choose an animate object. So for example, he predicted that a dot that stopped and started, and even changed direction, as it moved along the silent river scene, would be paired with the duck.

Adults were especially likely to pair their choice on picture trials with trajectories that were consistent with the forces present in the just-presented scene. Children's judgments were more variable due to the youngsters' tendencies to import force conditions that were not part of the setting display. For example, children who paired the leaf, and not the duck, with the trajectory that just moved in a force-inconsistent manner, "imported" a relevant force. They said that "the wind blowed it around," even though there was no sound of wind during the stimulus presentation. Their use of motion path information was only part of the information they used to construct a coherent account of the event and related causal sources of energy. The trajectories were an important, but not determining source of relevant information for the assignment of animacy. These were related to an overarching concern for relevant object-kind causal conditions. Thus, both children and adults were especially inclined to give motion explanations that were consistent with their judgments.

The formative role of causal principles is also illustrated in studies with photographic stimuli. Massey and Gelman (1988) asked preschool children whether novels item depicted in photographs could move themselves up and down a hill. The photographs were of novel animals (e.g., an echidna, a praying mantis, an invertebrate): wheeled objects, rigid complex inanimates (made up of parts that were leg-like, arm-like, etc.), and statues. Some children said the echidna could go up and down the hill because it had feet, even though none were visible. We also heard that a statue could not engage in such self-initiated actions because it did not have feet, even though it clearly did. A wheeled object might go down the hill, if something pushed it, but not up the hill. These comments reveal an active tendency to selectively attend and even reinterpret aspects of photographs with respect to causal considerations. The children were not simply interested in whether the photographed item had certain parts. These had to be intrinsic to animals. Thus they either denied that statues had legs or pronounced them "not real," "pretend," and the like. They tried, in their own way, to tell us whether an object was made out of the kind of stuff that goes along with the capacity for self-generated actions. As Williams (2000) put it, they were tuned into whether the causal of action was intrinsic to the

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kind of object depicted. Not only did these young children relate motion paths to their causal conditions; they seemed to distinguish between the causal conditions for animate and inanimate objects.

Subrahmanyam and Gelman (in press) reached a similar conclusion. One of their two studies involved a lengthy interview in which preschoolers (4- & 5-year-olds) were presented a battery of questions about 19 (verbally presented) objects. These included animates (person, dog, elephant, and bug), a plant and a rock, simple[1] artifacts (spoon, chair), "sentient" machines (TV, radio, computer, robot), moving machines (car, airplane, and robot), and so forth. One round of questions paired each item with six separate predicates (moves, talks, breathes, has a brain, thinks, remembers); another round asked about the insides and outsides of the objects; and a final round asked about the origin of each item.

Our expectations about the pattern of results were based on a consideration of the implications of the principle-first account of the animate–inanimate distinction. As a reminder, I argued that these principles are domain specific, not only because of different sources of causality, but because they are yoked to categorical different kinds of stuff. The fact that animate objects can cause themselves to move or change and inanimate objects cannot goes hand in hand with the fact that inanimate and animate objects are composed of different kinds of matter. Animate objects are made up of biological matter; inanimate objects are not.

Although all objects obey the laws of physics, animate objects also obey biochemical ones. In fact, the cause of animate motion and change comes from the internally controlled and channeled release of internally stored chemical energy that is characteristic of biological entities. Animate motions have a quality of function, purpose, or goal-directedness. This is a direct consequence of their governance by biological control mechanisms: these enable adjustments of, and coordination of, component actions, both as a whole and as separate components. These adjustments can affect social as well as nonsocial environments. The effect is an ability to adapt to unforeseeable changes in circumstances and interact with social and nonsocial environments. The cause of inanimate motion is an external force, and there is always a transfer of energy from one object to another or a conversion of potential energy to kinetic energy. This is the case even when a person serves as an agent. My view is that these facts about nature are deeply related to the way people come to distinguish between the general categories of animate

[1]The choice of *simple artifacts was based on a scaling study with an independent* group of adults.

and inanimate. Sets of different causal principles help us carve the psychological world at its joints, producing distinctions that guide and organize our differential reasoning about entities in one domain versus another.

The foregoing underlies my proposal that the real-world distinctions between the causes of animate and inanimate motions and transformations are captured by what I dubbed "innards" and "external-agent" principles. The idea is that higher order causal principles direct attention to a combination of information, including kind of matter, source of energy, and trajectories. As regards objects obeying the innards principle, the energy source for movements, transformations, perceptions, and interactions is intrinsic to biological objects and thus is contained within the objects themselves. In regard to objects obeying the external agent principle, the movements, transformations, and interactions of nonbiological objects are caused by agents and forces of nature that are external to the objects themselves. I make no commitment to what kind of explanation system individuals or cultures marshal to flesh in these principles. I only assume that these domain-specific principles serve to organize the uptake and coherent storage of relevant inputs, to help place young learners on relevant learning paths.

Given the assumption that there is the conjoining of material kind with the innards and external-agent principles, we predicted that young children would be disinclined to treat machines as clearly belonging to either the animate or inanimate categories. Basically, the idea is that young children would know that machines are made of the wrong "stuff" and move in the wrong way, although they appear to have the capacity for self-generated motion. Such facts would lead them to use a default strategy, the effect of which would be to start to create a new category (Subrahmanyam & Gelman, in press). To the extent that they could say anything about such devices, we expected them to refer to external agents or mechanisms. We thought it was also possible that they would mention the material as a way of saying that it was not animate. Finally, we did not expect them to be animists. We argued that it takes knowledge of both the animate domain and target objects to achieve animistic analogies. Put differently, the idea is that animism is part of an acquired explanation system.

The aforementioned line of reasoning avoids an unacceptable conclusion, this being that our young are endowed with principles that pick out machines per se. It hardly can be the case that there are innate skeletal causal principles for learning to identify machines.[2] They are

[2] Elsewhere, I discuss why only some domain-specific bodies of knowledge benefit from innate skeletal principles (Gelman, 1998; Gelman & Williams, 1998).

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cultural artifacts; especially ones designed to support travel and mimic sentient properties. More generally, I do not believe that young children, or even most adults, should be granted the kind of theory-rich knowledge about biology, chemistry, and physics that I make use of to develop the case that there are domain-specific causal principles and that these are skeletal in form. They can serve acquisition even if they constitute but nascent structures. For active minds use whatever mental structures are available to find and assimilate those kinds of inputs that can nurture the development of the knowledge base that can put flesh on these structures. Thus, to start, sets of first principles can serve to pick our relevant data and serve as memory drawers within which to keep together relevant learnings. This is a necessary condition for the acquisition of understanding.

Of course, it is one thing to place the material together in memory and another to reorganize it into a theory-rich account of a domain. The literature on this accomplishment makes it clear that acquisition of such understanding can be a long, arduous process (see Bransford et al., 1999, for a review). Considerations like these are why we were conservative about the depth of knowledge we expected. True, Subrahmanyam (Subrahmanyam & Gelman, in press) and I predicted that our preschool subjects would treat machines differently than either animate or nonmachine artifacts. We also expected that they would make some effort to tell us about causally relevant matters. However, we also were disinclined to think they would reveal coherent biological or mechanical understandings of why any class of objects belonged together (Carey, 1985, 1995; Gelman, 1991; Gelman et al., 1995). A sampling of the Subrahmanyam and Gelman (in press) findings serves to illustrate the lines of evidence that together confirmed these predictions.

First, as regards the matter of causal principles: Both the children[3] and adults answered questions in ways that showed they knew that machines are subject to different causal conditions than are animates—even if the machine can appear to move on its own or display sentient properties. When either age group explained their Yes–No answers about animates, they appealed to the presence of animate parts (e.g., bones, muscles, blood, mouth), causes (e.g., wants to move), and animate notions (e.g., alive, living) to justify their attributions. When talking about machines, they invoked the absence of animate features or the presence of inanimate parts (e.g., wheels), inanimate mechanisms (e.g., batteries, engines), inanimate materials (plastic, metal, hard stuff), and external sources of energy or agency (a pilot). As shown in the top half of Fig. 5.1, these explanation differences are re-

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lated to the pattern of Yes–No answers for the predicate MOVE. These data are plotted as a line graph given that we could use the adult data to generate an ordering of the various items shown on the X-axis. As can be seen, if anything, the adults were more inclined to attribute the capacity for motion to inanimate items—including a doll—than were the children. The reason for this was straightforward: the adults had a

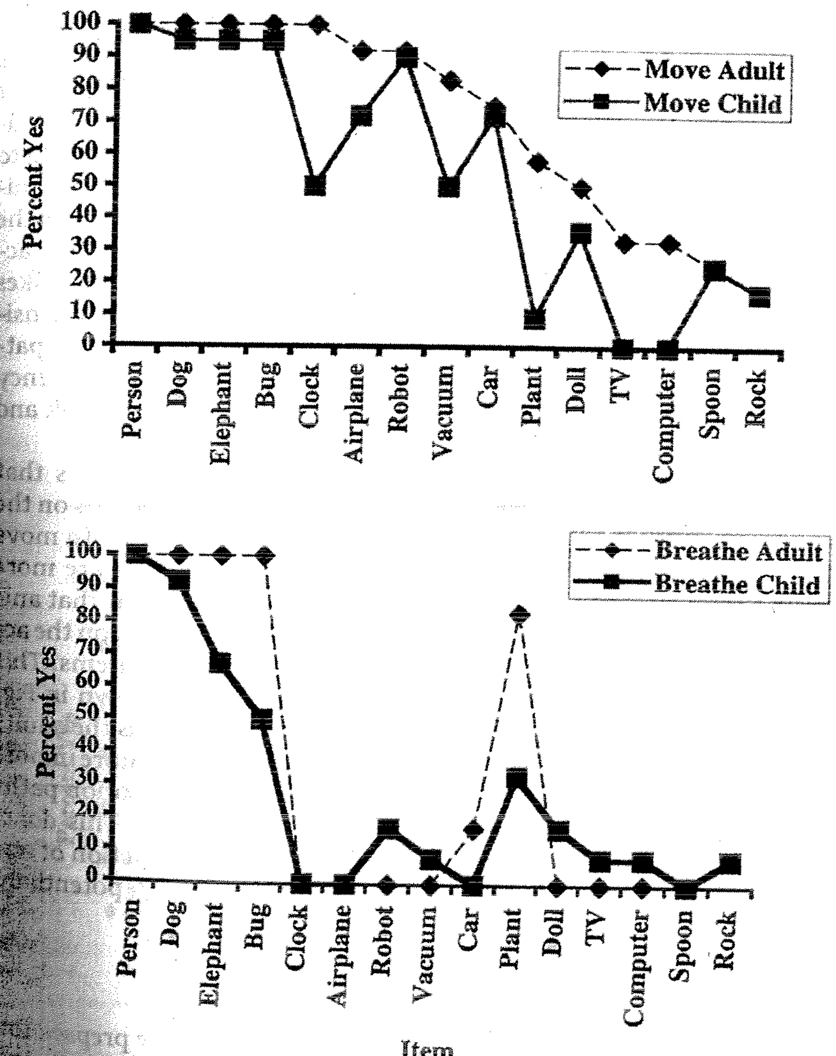

FIG. 5.1 Tendency of 4- and 5-year-old children as opposed to adults to say that various object kinds can move.

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richer repertoire of possible causal conditions, including their own capacity to move a computer, their knowledge about the computer devices that make dolls talk, walk, and so on. Thus, the more participants knew about mechanisms, the more they were able to move toward animistic attributions, regarding the capacity for the seemingly self-generated motion of machines. Here, then, is another way to make the point that the use of motion path is related to causal conditions.

As can be seen in Fig. 5.1, the pattern of attributions of animate properties to machines was selective in ways that we expected. It was consistent with the proposal that animates and machines are treated as different kinds of things. Still, knowledge about the different classes of objects would be rather shallow. The bottom half of Fig. 5.1 begins to illustrate this. Although the ability to breathe is selectively attributed to animates and plants, young children are far from certain that all animals and plants breathe. The generalization pattern shown here is the same as ones published by Carey (e.g., 1985). We concur with her account: The children do not have a biological theory, a theory that takes as given the capacity and structural wherewithal to engage in intrinsically generated air-exchange. This conclusion is buttressed by the patterns shown in Fig. 5.2. Notice the characteristic fall-off of the tendency of the children to attribute a brain as well as the capacity to think and remember to a dog, elephant, and bug.

We end by returning to the question of animism. Theories that characterize young children as animists place special emphasis on the fact that too broad a range of objects are granted the ability to move (Piaget, 1930). However, as we can see in Fig. 5.1, adults are more prone to do this than are young children. For us, this means that animism is a cultivated mode of thought, one that is dependent on the acquisition of knowledge about both the source and target items. This hypothesis gains support from the pattern of results shown in Fig. 5.2, which illustrates a clear developmental pattern. It was the adults who said computers and robots can remember. However, more importantly for this volume, it rests on the assumption that motion paths are causally categorized by domain-relevant principles. This done, knowledge and explanation systems will develop as a function of our active tendencies to engage in epigenetic interactions with potentially relevant environments.

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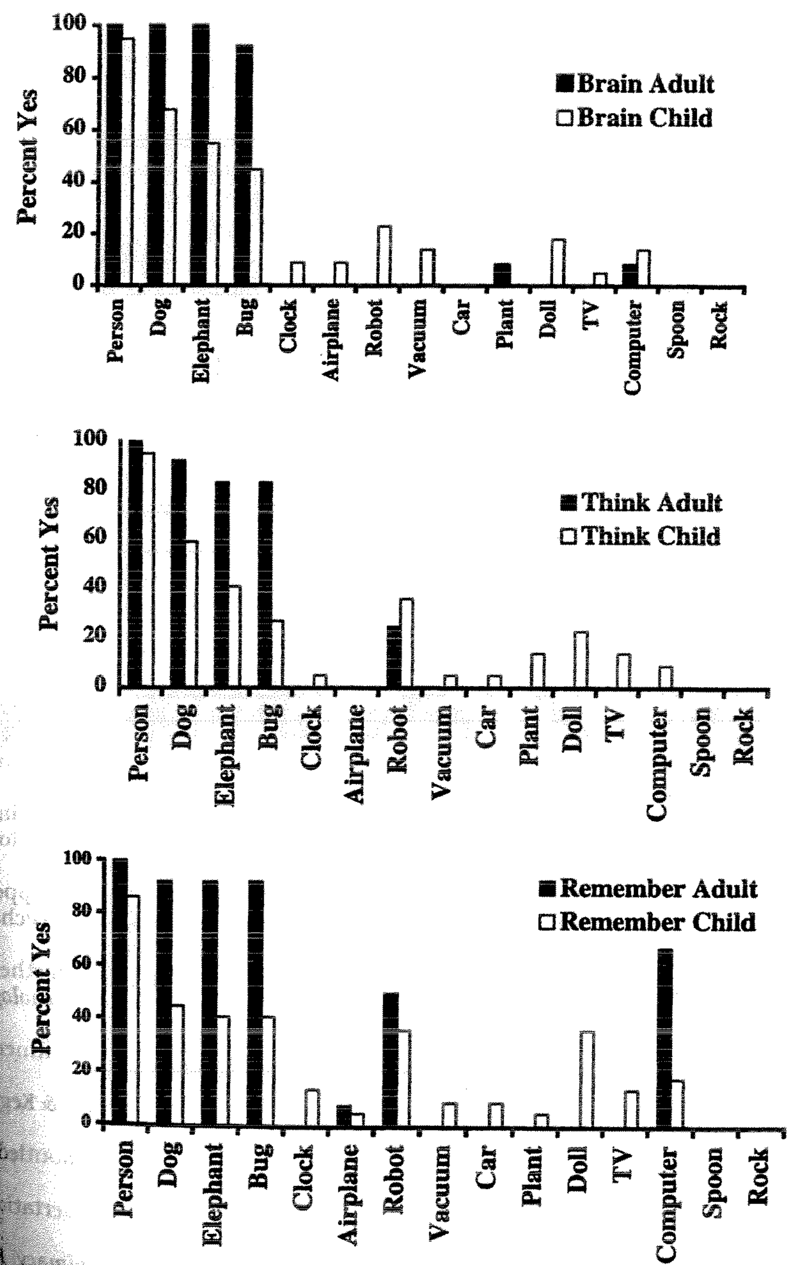

FIG. 5.2 Tendency of 4- and 5-year-old children as opposed to adults to say that various object kinds have a brain, think, and remember.

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