A World Apart:

How concepts of the constructed world are different in representation and in development

Frank C. Keil
Marissa L. Greif
Rebekkah S. Kerner

Department of Psychology
Yale University

A World Apart:
How concepts of the constructed world are different in representation and in development

Most children are surrounded, from birth, by a world of things created by the people who live around them and by the people who came before them. The very first act that infants perform on another object, that of nursing is often on a bottle designed for that specific purpose. In the months and years that follow, the world of artifacts will envelop the child. In this chapter, we contrast the development of children's understanding of artifacts with patterns of cognitive development in other domains, most notably that of living kinds and non-living natural kinds. We will focus on children who are no longer infants, although some discussion of artifact notions in infancy will frame what follows. The principal themes of this essay are the following: 1) There is far more variability in the patterns of development of childrens' intuitions about artifacts than about living kinds; 2) Because many insights about artifacts' origins and identity are likely to be "non-natural", initial conceptualizations of artifacts should be more difficult to acquire than those of most natural kinds; 3) As artifacts evolve and classes and subclasses of artifacts expand, associated patterns of concept acquisition may change quite radically; 4) Despite this diversity, the course of acquisition of the artifact concept may have some overarching developmental characteristics that are quite distinct from those of other kind domains; and, finally, 5) Understanding people's intentions may be very important to our concepts of artifacts, but initially at least, perhaps not in the ways we might think.

<u>The varieties of artifact kinds</u>

The literature in cognitive science often contrasts artifacts and natural kinds as though they were comparable levels in a standardized hierarchy of objects in the world. Although this distinction has featured prominently in many studies of cognition and cognitive development (e.g., Keil, 1989, Simons & Keil, 1995; Rips, 1989, 2001), it has the potential to mislead. Consider those frequent cases in which non-living and living natural kinds are associated with each other but are contrasted altogether with artifacts. Do the entire classes of living kinds and artifacts sit at roughly equivalent levels of generality in this putative hierarchy? It is clear that they do not. The domain of artifacts is much more varied and much less predictable in form and function than the domain of living kinds. Because of the heterogeneity of artifacts, the more appropriate contrast with living kinds would be an artifact sub class such as hand tools or furniture (Rosch et al., 1976). The reasons for this will become clear as we progress through this section. Indeed, this issue of generality is more than a quibble. A closer examination of the nature of artifacts reveals a vast domain with sub-domains that may differ at least as dramatically from each other as they do from the entire domain of living kinds. These differences have consequences not only for how adults represent and think about artifacts, but also for how children acquire concepts of artifacts. There is also the distinct risk of retreating to a very minimal characterization of what such a diverse set of entities shares in common, and thus the possibility of under-representing the extensive diversity of the artifact class.

This claim for greater diversity for artifacts is borne out empirically. In a series of studies by Keil and Smith (1996), for example, adults were asked to rate how much the category integrity of various kinds was disrupted by counterfactualizing typical properties (for instance, "To what extent is something that seemed to be a catapult still a catapult if it was twice as long and half as high as most other catapults?"). Peoples' responses indicated that separate sub-classes of artifacts seemed to group together each in their own discrete clusters. Unlike artifacts, the living kinds all tended to cluster together. In other words, changing typical color, size, or shape had roughly the same impact on all living kinds, whether they were ants or antelopes. By contrast, comparable changes on categories, such as vehicles and hand tools, yielded tight clusters within those two domains and large differences between them in terms of the profile of which properties matter the most and the least to their category membership. Similarly, patterns of developmental change in word meaning can vary considerably as function of artifact subdomains but not for living kinds (Keil, 1989). For instance, a young child might put excessive weight on a number of characteristic features at roughly the same time in conceptualizing hand tools but appreciate the same characteristic features at either younger or older ages for other artifact sub-domains. With living kinds however, once a child overrides typical features of a sub-domain, say lions, for an appreciation of deeper properties defining category membership, she is likely to do the same for most other living kinds. That is, unlike for artifacts, for most living kinds there is a relatively uniform shift in understanding that the underlying fundamental properties of one living kind apply to other living kinds as well.

There are other groups of artifacts that seem even more conceptually distant from the sub-classes of artifacts considered so far. A piece of art is clearly an artifact, but once art is included in the domain of artifacts, intangible artifacts such as performances, poems, and stories enter as well. Computer software, recipes and exercise routines would also seem to clearly be artifacts, as would social conventions such as driving on the right side of the road. To try to make a clear boundary between the physical and non-physical seems hopeless. Their inclusion in the general domain of artifacts poses a big problem for those who wish to describe the commonalities between all artifacts in physical terms. Because of the physical and functional diversity of items in the grand domain of artifacts, the best characterization of the commonalities of artifacts is that they are simply things that were intentionally created to help achieve some sort of goal. The goals in question vary considerably and include everything from communicating information, to surprising and delighting, and even to traumatizing and terrorizing.

Intuitively, however, one could argue that the entire class of natural kinds is also immense. After all, we need to consider instances of <u>both</u> living and non-living natural kinds. In addition to living kinds, there are elements such as gold, molecular compounds such as water, and even particular configurations of these molecules, such as carbon that can be formed into diamonds or into coal. For all of these there is a common story focusing on micro-structural elements and relations; but the details of that story – how such entities and substances come to exist - may vary considerably across those kinds. To make matters even more complicated, many other things have been called natural kinds for which an appeal to microstructures does not necessarily hold. These include volcanoes, glaciers, stars and planets. Instead of being strictly defined by their molecular makeup, these things seem to be the result of and maintained by complex processes that are often external to members of that kind, such as the laws of geophysics..

There is no denying that the natural world consists of a diverse set of entities. However, it may indeed be the case that for any one type of artifact, there exist an almost infinite number of variations in ontogeny, form, and function. This is not the case for natural kinds. To make any progress in highlighting the important differences in conceptualizing artifacts and natural kinds, we need to assess artifacts against a comparable standard. For the remainder of this essay we will often contrast the class of living kinds, the most discussed case of natural kinds, with artifact subcategories such as tools or furniture that correspond to bounded and enduring physical objects and will consider some of the patterns that emerge from such contrasts.

Cues to "artifacthood"

Long before they can speak, children may sense that the world of artifacts is different from the natural world. There is a huge array of perceptual patterns that set most physical artifacts apart from items in the natural world. For example, many classes of artifacts are much more rectilinear than most natural kinds. Their junctions are often at right angles and are signaled by dramatic color shifts as well protrusions or indents that correspond to the angles (Levin et al., 2001). Straight lines and equal interval spacings of components are comparable cues. Texture is also often a cue, with many artifacts having smooth surfaces in contrast to the fractal character of many natural surfaces. Artifacts tend to have striking uniformity of size for members of local categories while natural kinds usually do not. While a group of the same kind of chairs or spoons will often be physically identical because of the nature of mass production, even those most closely related members of a subspecies will usually show considerable variation in size, color and even shape. Non-living natural kinds, such as glaciers, stars, and diamonds, often show even more physical variation.

Thus, long before they understand much about the use or origins of artifacts, children may see them as somehow different and distinct from the natural world. They may not necessarily know that artifacts are created by other humans and that natural kinds are created by natural processes, but they are likely to see that they are different domains of things (e.g., Simons & Keil, 1995; Mandler, 2002; Mandler & McDonough, 1993, 1996, 2000). Other differences are evident over time. Artifacts do not grow or have periods of fragile infancy (Hatano & Inagaki, 1996). They are also not usually functional until they are complete. A half-built car doesn't run, and a half-made shirt might not be wearable. By contrast most living kinds must function in some crude way from the moment of their conception, one of the great organizing principles of developmental biology (Gilbert, 2000). An infant animal is just as much a complete and functional animal as is an adult and, similarly, an ailing adult is still as much an animal as a healthy one. The basic mechanics of life must be sustained throughout development for that living organism to continue existing as a living organism; but a chair does not have to function as a chair until it is complete. Children surely witness this difference on many occasions. A related difference is that the path of creation of an artifact is largely arbitrary as long as the end state is the same. A chair made with the legs attached to the seat first is the same chair as another made from the same parts but with the back attached to the seat before the legs. By contrast living kinds, even those that undergo dramatic metamorphoses, always follow the same path of creation, which indeed helps to define the final state. This difference is one that is sensed by quite young children (Keil, 1989).

The large range of cues that correlate with artifacts may therefore enable very young children to see this hugely diverse class as somehow different from the biological world. The key question is what follows from such an awareness. Do young children explore artifacts differently from natural kinds? For example, are their manual explorations and their questions about artifacts different then they are for living kinds? Do they sometimes seem to ask more “What is that for” kinds of questions about artifacts than about various natural kinds? As adults, we tend to treat whole artifacts as having purposes (hence the sensible nature of questions such as “What is a protractor for”, but not infer or inquire about general purposes for whole natural kinds (e.g., What is a tiger for?, what is a planet for?). Detailed analyses of spontaneous speech have not been done and so it remains a conjecture as to whether young children tend to ask different sorts of probing questions about the two kinds. Similarly, childrens’ patterns of visual or tactile exploration might be different for artifacts and natural kinds. For example, a young three old, on encountering a strange small detached artifact, may pick it up and try to use it on yet a third object through pounding or pushing. That tendency may be less common when picking up a strange detached living kinds such as an unusual fruit. These patterns, however, must remain speculations until further studies are conducted.

There is evidence that at a more explicit level, young children have difficulty judging whether such whole object statements of function apply solely to artifacts but not to natural kinds. They will sometimes argue that both tigers and rocks have overall purposes as well (Kelemen, 1999). Another important area of research on children’s understanding of function involves the degree to which children can understand the link between different types of teleological causation and different kinds of objects. One ongoing study is looking at how children understand different types of teleological explanations for living kinds and artifacts. For example, one might hear about a hat that has fur on it or an animal that has fur on it, and be asked to judge the ultimate function of the fur for both of those cases (Kerner and Keil, in preparation). In such cases, it appears that children as young as five years of age may be able to appropriately determine whether artifacts and living kinds have features to help themselves or to aid others. Thus, young children may have a sense that even the purposes for parts of things differ by domain.

There are other patterns at the conceptual level that may be used to distinguish artifacts and natural kinds. One conceptual difference revolves around the causal centrality of typical salient features (Ahn, Kim, Lassaline, & Dennis, 2000). It can be difficult to define a “feature” in the first place, as one could think of a great multitude of ways to divide up a toaster or a tiger into parts, and continuously redefine which features they want to include in a set belonging to an identity. But by any reasonable notion of feature, those of artifacts are often seen as causally irrelevant to being that artifact whereas comparable features for natural kinds are seen as central to their existence. We tend to assume that most features of natural kinds play causal roles for them, some of moderate importance some of great importance, but few that are irrelevant. Thus, for tigers, surface markings and shape are both assumed to be important to tigerhood. But the color and surface markings of most vehicles or most items of furniture are considered unimportant, when considering the status of such artifacts as members of that kind (Keil, 1989). We assume that there are no accidents for features of natural kinds but freely accept the idea that some features of artifacts may be accidents or merely conventions. Indeed the tendency to assume that there are important causal roles for virtually all features of living kinds has been deemed a misleading cognitive bias (Gould and Lewontin, 1979), and the assumption that most all traits are naturally selected-for adaptations is an idea of much contention among evolutionary biologists and psychologists (Gould, 1997). Interestingly, this pattern of assumptions seems to be pretty much the same in children as young as five years of age who tend to think that, for natural kinds, almost all features matter, while for artifacts only a small subset of features have purposes (Keil et. al. 1998).

It seems therefore that there are many distinctive patterns to most artifacts that occur at both perceptual and conceptual levels, and that children as young as five years of age are very much aware of these patterns and use them to reason about artifact category membership, property induction and other concept related tasks. More importantly, these different patterns can arise without invoking intentions of the artifacts' creators at all. Thus, long before children are making specific inferences about specific intentions of artifacts' creators they may be reasoning about artifacts in highly distinctive ways and set them apart from natural kinds.

Conceptual Complexity and Naturalness of Artifacts

One of the consequences of artifact diversity is that some artifacts are conceptually very difficult to apprehend. This is, generally speaking, not the case for most living kinds. If you teach a person about a new living kind at the species level by pointing to a few exemplars, that person will usually have pretty good success at subsequent identifications (Keil, 1994; Atran, 1998). The same may be true for many simple hand-tools or items of furniture, but other classes of artifacts have purposes embedded in highly technological and/or cultural niches that make them meaningless unless an individual has a real understanding of that context. A good example of this is a class of devices known as Differential Global Positioning System (GPS) Receivers. Normal GPS receivers receive data about the location of GPS satellites at any given time and the time it takes for the signals from the satellites to travel to the Earth. With just three signals, the receiver can calculate the coordinates of your position on the ground. This device was originally designed by the military; as the technology was released to the civilian public, the capacity for accurate calculations of location was made less precise. The Differential GPS Receiver is a correction device that compares GPS signals to known landmarks and then sends correction signals to GPS receivers that makes them much more accurate. To correctly identify such a device requires knowledge of how GPS receivers generally work, knowledge of the military's strategy to downgrade civilian versions of the signals, and the relation between the two. Countless other examples exist.

Even where the structural complexity of an entity is not readily observable, the functional complexity requires a great deal of knowledge of social and cultural scripts for the object's use. For instance, the ATM Debit/Check card functions as a form of payment and is often seen being swiped through some sort of detection device. How the card works and by what mechanism are not visually apparent. Knowledge of its membership in a category requires reasonably advanced knowledge of trade and commerce in modern Western society, as well as some comprehension of the technology of data storage. There seems to be no upward limit on the potential complexity of artifact categories and levels of knowledge required to be able to successfully identify members of such a category. There are of course arcane cases in biology where species are confused, but rarely if nowhere in the domain of living things will you find whole classes of physical entities that cannot be categorized at the basic level upon visual inspection. There are some conceptually awkward living kinds (Hull, 1965) but it is rare to stumble into an environment and be as clueless about the identity and function of biological entities and their parts in the same way as we can be for many artifacts.

There are of course conceptually deep issues in the natural sciences that can be extremely difficult to grasp, which can involve categorization of entities based on deep theoretical principles and not on more physically obvious traits. Examples include classification of a compound as a superconductor, or a molecular structure as a transcription factor, both of which require a great deal of specialized knowledge unavailable to all children and most adults. But again, these exceptions are beyond the parameters for comparison that we set out for ourselves at the beginning of this paper– that we consider bounded enduring objects. There usually is at least one inductively rich way to categorize a group of natural kinds that is that available to most people. In walking through a strange ecosystem, one is often able to group new kinds of animals and plants quite easily and without any sort of explicit instruction. To be sure there can be confusions between legless lizards and snakes, or aquatic mammals and fish, but for the most part the entities in the domain of biology are easily categorized (Atran, 1998). There is a grain of an analysis for almost all samples of the macrocopic living world that is easy to grasp. In contrast, if one enters a strange laboratory or manufacturing facility, one may be completely at sea with respect to how to categorize the objects one encounters. In this way, despite being created by human minds, some artifacts are conceptually quite non-natural and require detailed local knowledge[1]. For living kinds, such as for various animal species and their subordinates and superordinates, such difficulties seem to be far less common.

Why should we expect this divergence between artifacts and living kinds in terms of ease of early categorization by young children? One answer might lie in the ways in which instances of the category are related in a hierarchy or taxonomy   There is an immediate and compelling sense that living kinds are embedded in a unique taxonomy that is not arbitrary (Atran, 1998). For most artifacts, however, it seems that many alternative hierarchies are possible for the same kinds. Indeed, some artifacts do not seem to fit easily into any hierarchies at all. For example, a fancy stereo system can be placed in a hierarchy of furniture, of electronic devices, or of toys. An intricately carved knife may be categorized as art to hang on one's wall, as a kitchen utensil, as a digging tool for use in the garden, or as a weapon. Similar problems are obvious when one tries to come up with a definition of even simple artifacts, like chairs. There are no obvious physical characteristics that are shared by all chairs, and there is great flexibility in what physical characteristics any one chair can possess. To complicate matters further, some artifacts do

---

[1] More intuitively, it seems obvious that some classes of artifacts, such as basic hand tools like scissors or hammers might be easy for a preschooler to learn well enough to categorize fairly successfully; while others, such as diagnostic tools used by a computer repair technician might not be accurately conceptualized until many years later.

not seem to fit into in any organized hierarchy or conceptual structure whatsoever. Is a handkerchief a piece of clothing? Is a lamp a piece of furniture? Unlike natural kinds, for artifacts, there is no strong sense of a unique solution to the hierarchy issue. It may be that artifacts are more easily and more consistently categorized by thematic rather than taxonomic relations (Lin & Murphy, 2001). Because artifacts can be assigned a variety of purposes or functions, a binding theme or context may be just the factor that can provide cues to a particular artifact's identity as a member of a particular category. This allows artifacts to maintain multiple identities simultaneously, and potentially avoids the difficulty of assigning any one artifact to an immutable singular position in any one hierarchy. In this way, a sword can be both a work of art and a weapon; the primacy of any one identity would depend heavily on other cues in the context in which the object exists and the other objects it is related to it that context (Barsalou, 1983).

Thus, even when the class of artifacts is restricted to physically bounded objects, they can vary greatly in their conceptual naturalness as individuals and in the extent to which they systematically relate to other kinds. The dilemma for conceptualizing artifacts is parallel to deciding membership in multiple categories governed by ad-hoc rules. The dilemma for living kinds, conversely, lies in placing each kind in a hierarchy whose taxonomy is restricted by laws of genetics, speciation, and evolution.

How Children Learn about Artifacts

In conversations with children, adults are unlikely to provide definitions about the meanings of words or discuss an object's membership in a category. That is, they often label objects but rarely define them or explain their nature to children (Gelman, Coley, Rosengren, Hartman, & Pappas, 1998). With this dearth of direct semantic instruction, what information do young children use to learn about artifacts? Two forms of information may dominate conceptualization early on: Direct perception of an object's affordances, and attention to contexts surrounding goal satisfaction. Both factors may influence children's notions of artifacts, though in very different proportions depending on the particular artifact in question

Most objects have been said to have "affordances", ways in which the layout and material properties of substances provide potentials for action by and interaction with an agent (Gibson & Adolph, 1999). By this theory, affordances are invariant and "directly perceived" features of objects that relate information about the utility of various surfaces and objects for behavior. They are not constructed via inference mechanisms. That is, one should immediately see an object as a container, a barrier, a supporter, or a handle and act on it in an appropriate manner, even when it is a highly novel object. We might conclude then that one of the earliest ways in which artifacts are distinguished is in terms of their different affordances. A preverbal infant, for instance, may see some surfaces as excellent for walking or sitting on (Gibson et al., 1987). Investigations into early notions of physics suggests that infants as young as 4 months can recognize that falling objects cannot pass through a solid horizontal barrier (Spelke, Breinlinger, Macomber, & Jacobson, 1992). Hence, here an object, a horizontal plane made of a particular material, may be perceived as appropriate for performing a particular action -- traversing. In this sense, an artifact is understood as part of a direct interaction between agent and object.

A second sense of affordance may involve the perception of an object as a causal mediator between an agent and another object. This intuition is more likely to be distinctively associated with artifacts. Hand tools such as hammers and knives are just two examples. Not only are they directly perceived as graspable, they contain their own surface and material properties that can aid agents in transforming and acting on objects in particular ways. For instance, hammers generally have solid heavy parts that can pound other objects. Likewise, knives have thin sharp edges appropriate for cutting. Large containers generally have cavities in which other smaller objects can be placed. This second sense of affordance has been studied less directly although some work does suggest some emerging understanding of objects' roles as containers by 17 months of age (Baillargeon, 1998, Caron, Caron, & Antell, 1988) and as pulling devices by 9- and 12-months of age (Schlesinger and Langer, 1999). Moreover, it seems that by 18 months of age, infants demonstrate some understanding of the link between form and function (Madole & Cohen, 1995; Madole, Oakes, & Cohen, 1993). Kemler Nelson et al. (1995) found that 3-, 4-, and 5-year olds categorized artifacts as either painting devices or musical instruments based on the functional affordances that particular crucial features specified.

Despite its clear phenomenological appeal, the notion of affordances remains frustratingly vague. Even under the most optimistic and charitable interpretations of affordances, it is clear that many artifacts do not offer their functions up so easily to direct perception. For example, without any other information, no amount of visual inspection of an antibiotic pill or credit card will reveal its function. There is, however, an alternative way to learn about artifacts that, like affordances, does not involve any explicit instruction by adults. Imagine a child watching for the first time an adult using a key. Inspection of the key itself is very unlikely to yield insight into its function since its most important functional parts, its serrations, interact with the parts of a lock that are not visible from the outside. Yet very young children come to learn what keys are for or what they do -- and usually without being told. They do so by watching an actor with a goal perform an action, such as opening a door, and observe the key being central to goal satisfaction, the opened door. Whether it be keys, television remote controls, glue sticks, or metal detectors, an artifact's global function can be understood without knowing how its form is related to its function and, it would seem, without knowing that someone made it for a particular purpose.

Inferring function from an actor's intentions, however, is a more subtle process than it first appears. A basic problem of inference lies in the mapping of an object's function to the relevant goal in a sequence of actions. It is necessary decide which of the many actions involved in satisfying a goal are linked to the function of the artifact the agent is using. A child should not infer, for example, that the person uses a key because they like the felt sensation it creates in his or her hands, or because it is useful for making a nice sound when jangled against other keys. The determination of the relevant function of the object lies in noticing the way in which it is used to create an end-state that matches a person's initial intentions. …

Another challenge for inferences about function is to decide how general any one object's function is in relation to the other objects with which it interacts. A person's immediate goals may be highly specific, (e.g., "I want to attach together these particular pieces of paper"), but the inference of, in this case, the tool's function may not be as distinctly mapped to the object upon which it is first used. Thus, a significant question for further distinguishing the functional properties of artifacts is to ask at what level of generality do children and adults internalize their inferences about function? Is the glue stick understood as only effective for those two pieces of paper, or just for pieces of paper of that size, shape and color? Or is it understood as able to glue together wood, metal, glass, and fabric? Is there a happy medium between the tool satisfying a global goal and performing a specific operation on a specific material? That is, is a glue stick a global "attacher", a local " paper gluer", or something in between? For inference to have any value the child must abstract away the appropriate function at a sufficient level of generality to be of some use in other contexts, otherwise we would need an infinite number of tools to solve an infinite number of problems.

Experimental work is just beginning to address this method of learning about artifacts, and tools in particular (Greif & Keil, in preparation). In one paradigm, children observe a video of an actor trying to achieve a goal, such as opening a wooden box, joining two pipes, or cleaning off a pile of dirt from a table. The actors display frustration at not being able to do so with their bare hands and are shown embarking on a search for a tool to solve their problem. After finding a tool that will help them, their moods shift to satisfaction as they are subsequently shown with their initial goals satisfied (for instance, with an opened box, or with a clean table). The videos never show the tool itself, its manner of use, or hear statements referring to the function of the tool, rather the scenarios imply its role through goal satisfaction. Finally, the children are shown photos of variations of objects from the initial problem scenario. The objects in the photos vary on dimensions of color and size, on their material and form, and the appropriate function required to fulfill the actor's goal. Children are asked to decide which variations will be solved by the unseen tool used in the target video.

There are two key questions to this work: 1) Are children able to infer function from the goals set up in videos? and 2) At what level of abstraction do they make such inferences? The research is still under way but it is already clear that children at least as young as five years easily infer functions from goal satisfaction episodes and that they do so in roughly the right conceptual space, that is they infer some subclass of opening devices for an situation where adults judge that the goal is opening. With respect to the second question, young children are not completely specific (e.g., assuming it is only a tool for opening red wooden boxes) but seem to be considerably more narrow in their generalizations of tool function than older children. This result may be driven by an effort to think of a known tool (for instance, a screwdriver to pry open stuck edges of a wooden box), and to assume that the tool the actor uses is a member of that category. By positing a familiar tool, young children may then use whatever they know about that tool's mechanism to reason about its utility on other objects. It may be that their knowledge of tool mechanism is, in fact, limited compared to that of an older child or adult. With more unfamiliar tasks for which familiar tools will not work they may be just as or even far more abstract than older children in terms of generalization of function. By using unfamiliar tools, the knowledge of mechanism is erased for all age groups. Ultimately, the rationale underlying this line of research illuminates the notion that young children are quite adept at making inferences about tool use on the basis of goal states of others, while apparently not having to know that artifacts themselves are designed by humans.

Within this account, there should be a critical distinction between differentiating artifacts from natural kinds and thinking about what it means for something to be an artifact in and of itself (that is, to come to understand what properties and characteristics define artifacts in and of themselves). It may be that these two facets of cognition about artifacts develop quite independently of each other. It may seem at first that the core that distinguishes between artifacts and natural kinds is to know that artifacts were made by agents with goals and intentions and that the intention of the creator is paramount (Bloom, 1996, 1998). Explicitly knowing that artifacts are things made by intentional agents may indeed be the only way to really understand what artifacts are as such, especially for the entire class of artifacts, and especially as they stand compared to natural kinds. The next task is to refine knowledge of the properties of subclasses of artifacts and individual instances of those classes. From the historico-intentional account of artifact identity, we should already know that looks are not always what they seem. Though structure may provide some cues to function, it is a relatively unreliable indication of an artifact's category membership. But because children very rarely see people actually <u>create</u> artifacts and very often see people <u>use</u> artifacts, it is reasonable that this second kind of information is especially informative early on before children understand all of the intricacies of designer intent. For instance, assessing real-time goal-fulfillment requires the ability to infer current intent of a physically present entity. This is a somewhat different, and seemingly simpler, cognitive task than making hypotheses about the beliefs and desires of a frequently absent individual who performed some creative act in a past context.

We do know that young children, well before the first year of life, are quite sensitive to a person's intentions and will imitate an action they believed an agent wanted to engage in rather than the one they actually performed (cf. Meltzoff, 1995). They also demonstrate surprise at actions that fail to reflect the assumed intentions of an agent even when those actions might be physically identical to ones performed earlier (Woodward, 1998; Gergely et al.., 1995). Moreover, Matan and Carey (2001) found that even children as old as four years have difficulty understanding the notion of designer intent as the determinant of original function. German and Deyfeyter (2000) also noted that five-year-old children were not influenced in a problem-solving task by notions of "proper" or original function. All of this suggests that current goal fulfillment may be an important way that very young children account for artifact function and categorization.

<u>What Changes with Development?</u>

What is different about the young child's concept of artifacts in comparison to an older child or an adult's concept of artifacts? One major change may be an increasing appreciation of intended function in contrast to salient current function. Though the two usually coincide, it seems to become more obvious with time that the intended function should trump all else in assigning membership to artifact categories. One elegant demonstration of this pattern occurs in work on children's drawings. Three- and four-year-olds labeled pictures they had drawn themselves according to their own intent to create a representation of an item such as a lollipop or balloon; this was despite the indistinguishable appearance of their renditions of the two objects (Bloom & Markson, 1998). Children were also able to determine the appropriate labels for pictures that others had drawn given information about the artist's intent. Gelman and Bloom (2000) also found that three-year-olds were more likely to provide artifact names for objects that an experimenter indicated had been intentionally created.

Evidence provided by Matan & Carey (2001) suggests, however, that a comprehensive understanding of the role an intentional designer plays in determining the identity of an artifact does not start to emerge until around six years of age. It is possible that as children get older they are more likely to explicitly think about how the artifact might have been created and if that manner of creation is consistent with the function they have inferred through observation. However, the first pass at determining artifact identity may indeed be by observation of how an actor currently uses an artifact to fulfill particular goals. This is supported by work done by Mandler and McDonough (1996, 1998) and again by Matan and Carey (2001), and German and Defeyter (2000). Mandler and McDonough's studies have demonstrated that infants between 14- and 24-months begin to understand the appropriate uses and actions on artifacts (and do so more accurately than for living kinds at first) and demonstrate this by imitating modeled acts.

Another type of knowledge that should be implicated in a developmental account of a concept of artifacts is the ever-increasing database of information about the mechanisms involved in any artifact's function. Children may often get the only the highest level of functional gloss for any artifact and then only gradually fill in the detailed knowledge about the more precise mechanisms that subserve that larger function. Thus, they might know that a camera is for taking pictures, but have no idea of how images are captured, processed and represented. This understanding should grow over time as children are exposed to more and more technological minutiae through experience and formal instruction. The consequence of this increasing mechanistic knowledge may be to yield better insights into how such a device was originally designed and created, thus bringing together both the intuitions of intentions of users with those of creators.

Third, we should expect that as artifact concepts develop, children and adults should come to understand that the identity of artifacts might easily jump across category hierarchies in ways not possible for living kinds. Something that might have been initially identified as a piece of jewelry may later be categorized as a time telling device. Something that was initially understood to be a toy later may be conceptualized as a word processor. Not only can these artifacts be re-categorized, they can maintain membership in concurrent categories quite easily. These kinds of dramatic leaps are far less common for the living world. A member of a living kind might be categorized as both a basic-level and superordinate-level kind – an animal categorized as a cat might also be categorized as a mammal. It is less likely that a species of cat would concurrently be categorized as a dog; this would clearly be an assignment error. Again, an increasing tendency to view artifacts as flexibly belonging to more than one category would rely heavily on a growing understanding of intended design, use and mechanism.

Finally, one of the most subtle and latest emerging insights concerning artifacts may be to understand the ways in which they are often co-mingled with natural kinds. Hunting dogs, race horses, and dairy cows are artifacts created by intense breeding practices. Human actions and intended function have transformed many of the salient properties of these animals. Similar phenomena can be found across many species of animals and plants and can be quite dramatic with modern technology. Researchers have, or example, discovered ways to express genes for spinning spider's silk in bovine cells with the ultimate purpose of producing such silk in a much more economical fashion (Lazaris et al., 2002). Similarly, farmers in Japan have produced square watermelons in order to optimize shipping and storage density. Perhaps one of the factors prohibiting easy re-categorization of such cases is the level of salience of the essences of natural kinds. Not only does one need a somewhat broad knowledge base of technological advances that permit transformations between natural kinds and artifacts (and the ill-defined line that divides them), the driving intuition that natural kinds have particular steadfast essences prevent a full understanding of how natural kinds can become artifactualized. For instance, knowing something is a living kind permits a number of inferences about its properties – that it reproduces, respires, that member of a category share internal parts and a similar path of development (Gelman & O'Reilly, 1988; Hatano & Inagaki, 1996; Keil, 1989; Keil, 1992; Simons & Keil, 1995). When artifactualizing a living kind, a serious cognitive conflict arises. These types of essential properties are hard to remove from a living kind and still deem it living, and they are almost impossible to bestow upon artifacts without a miraculous act or an incredible feat of science. In the cases of entities like square watermelons and hunting dogs, just looking at them provides many cues to their living status (i.e., that these vital characteristics have not been withdrawn). Clearly, the essential characteristics of living kinds are maintained, and given all we know about watermelons and dogs, the intuition that these beings are living kinds is just too compelling to ignore in favor of less obvious cues to artifacthood. Not only should the ability to transcend this conflict be late-developing, some adults may never fully understand the dual status of these entities.

Conclusions

Humans show an extraordinary ability relative to all other species to create and learn about artifacts. Some of this special ability may revolve around a more sophisticated ability to see affordances. We may even perceive affordances on a relational level; that is, not only do we see the structural/functional capacity of an object itself, we see the ways in which it can be used on other objects. However, we also have a more sophisticated ability for reasoning about the features of artifacts that is less relevant for understanding aspects of living kinds. Our ability to infer the intentions and goals of others helps us to identify and refine our categorization of a seemingly infinite class of artifacts. While this ability could play an obvious role in thinking about how an artifact was originally created, it may figure in an equally if not more important role early on in determining the functions of artifacts in real time through looking at goal satisfaction in others. Although it seems that even infants may conceive of natural kinds and artifacts in different ways, with development, the processes that aid in our understanding these domains help us distinguish them in much deeper and more elaborate ways.

References

Ahn, W-K., Kim, N. S., Lassaline, M. E., & Dennis, M. J. (2000). Causal status as a determinant of feature centrality. *Cognitive Psychology, 41,* 361-416.

Atran, S. (1998),Folk biology and the anthropology of science: Cognitive universals and cultural particulars. *Behavioral & Brain Sciences, 21,* 547-609.

Baillargeon, R. (1998). Eight-and-a-half-month-old infants' reasoning about containment events. *Child Development, 69,* 636-653.

Barsalou, L. W. (1983). Ad hoc categories. *Memory & Cognition, 11,* 211-227

Bloom, P. (1996). Intention, history, and artifact concepts. *Cognition, 60,* 1-29.

Bloom, P. (1998). Theories of artifact categorization. *Cognition, 66,* 87-93.

Bloom, P., & Markson, L. (1998). Intention and analogy in children's naming of pictorial representations. *Psychological Science, 9,* 200-204.

Caron, A.J., Caron, R. F., & Antell, S.E. (1988). Infant understanding of containment: An affordance perceived or a relationship conceived? *Developmental Psychology, 24,* 620-627.

Diesendruck, G., & Gelman, S. (1999). Domain difference in absolute judgments sof category membership: Evidence for an essentialist account of categorization. *Psychonomic Bulletin & Review, 6,* 338-346.

Gelman, S. A. & Bloom, P. (2000). Young children are sensitive to how an object was created when deciding what to name it. *Cognition, 76,* 91-103.

Gelman, S., Coley, J., Rosengren, K. S., Hartman, E., & Pappas, A. (1998). Beyond labeling: The role of maternal input in the acquisition of richly structured categories. *Monographs of the Society for Research in Child Development, 63.*

Gelman, S., & O'Reilly, A.W. (1988). Children's inductive inferences within superordinate categories: the role of language and category structure. *Child Development, 59,* 876-887.

Gergely, G., Nadasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56,* 165-193.

German, T. P., & Defeyter, M. A. (2000). Immunity to functional fixedness in young children. *Psychonomic Bulletin and Review, 7,* 707-712.

Gibson, E. J., & Adolph, K. (1999). Affordances. In R.A. Wilson & F. C. Keil (Eds.), *The MIT Encyclopedia of the Cognitive Sciences* (pp. 4-6). Cambridge: MIT Press.

Gilbert, S.F. (2000) Developmental Biology. 6th ed., Sunderland, Massachusetts: Sinauer Associates, Inc.

Gibson, E. J., Riccio, G., Schmuckler, M. A., Stoffregen, T. A., Rosenberg, D., Taromina, J. (1987). Detection of the traversibility of surfaces by crawling and walking infants. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 533-544.

Gould, S. J. (1997). Darwinian fundamentalism. *The New York Review of Books,* 27-30.

Gould, S. J., & Lewontin, R. C. (1979). The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme. *Proceedings of the Royal Society of London, B205,* 581-598.

Hatano, G., & Inagaki, K. (1996). Young children's recognition of commonalities between animals and plants. *Child Development, 67,* 2823-2840.

Hull, D. (1965). The effect of essentialism on taxonomy: 2 000 years of stasis. *British Journal for the Philosophy of Science, 15, 16,* 314-326, 1-18.

Keil, F. (1989). Concepts, Kinds, and Cognitive Development.

Keil, F. C. (1992) The origins of an autonomous biology. In M. R. Gunnar & M. Maratsos (Eds.), *Minnesota Symposia on Child Psychology: Vol. 25, Modularity and constraints in language and cognition.* Hillsdale, NJ: Erlbaum.

Keil, F. C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In L.A. Hirschfeld & S. A. Gelman (Eds.) *Mapping the Mind: Domain Specificity in Cognition and Culture.* Cambridge: Cambridge University Press.

Keil, F.C, Smith, W.C., Simons, D., and Levin, D. (1998) Two dogmas of conceptual empircism, *Cognition, 65,* 103-135

Keil, F.C. & Smith, W.C. (1996) Is there a different "basic" level for cause? Paper presented at the 1996 meeting of the Psychonomics Society, Chicago.

Kelemen, D. (1999). The scope of teleological thinking in preschool children. *Cognition, 70,* 241-272.

Lazaris, A., Arcidiacono, S., Huang, Y., Zhou, J-F., Duguay, F., Chretien, N., Welsh, E. A., Soares, J. W., & Karatzas, C. N. (2002). Spider silk fibers spun from soluble recombinant silk produced in mammalian cells. *Science, 295,* 472-476.

Lin, E. L., & Murphy, G. L. (2001) Thematic relations in adults' concepts. *Journal of Experimental Psychology: General, 130,* 3-28.

Levin, D. T., Takarae, Y., Miner, A. C., & Keil, F. (2001). Efficient visual search by category: Specifying the features that mark the difference between artifacts and animals in preattentive vision. *Perception & Psychophysics, 63,* 676-697.

Kemler-Nelson, D., & and 13 Swarthmore students, (1995). Principle-based inferences in young children's categorizations: Revisiting the impact of function on the naming of artifacts. *Cognitive Development, 10,* 347-380.

Madole, K. L., Oakes, L. M., & Cohen, L. B. (1993). Developmental changes in infants attention to function and form-function correlations. *Cognitive Development, 8,* 189-209.

Madole, K. L., & Cohen, L. B. (1995). The role of object parts in infants' attention to form-function relations. *Developmental Psychology, 31,* 637-648.

Mandler, J. M. (2002). On the foundations of the semantic system. In Emer M. E. Forde & Glyn W. Humphreys (Eds.), *Category Specificity in Brain and Mind.* New York: Psychology Press.

Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development, 8,* 291-318.

Mandler, J. M., & McDonough, L. (1996). Drinking and driving don't mix: Inductive generalization in infancy. *Cognition, 59,* 307-335.

Mandler, J. M., & McDonough, L. (1998). Studies in inductive inference in infancy. *Cognitive Psychology, 37,*

Mandler, J.M., & McDonough, L. (2000). Advancing downward to the basic level. *Journal of Cognition and Development, 1,* 379-403.

Matan, A., & Carey, S. (2001). Developmental changes within the core of artifact concepts. *Cognition, 78,* 1-26.

Meltzoff, A. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31,* 838-850.

Rips, L. J. (1989). Similarity, typicality, and categorization. In S. Vosniadou & A. Ortony (Eds.), *Similarity and Analogical Reasoning.* Cambridge, UK: Cambridge University Press.

Rips, L. J. (2001). Necessity and natural categories. *Psychological Bulletin, 127,* 827-852.

Rosch, E., et al. (1976). Basic objects in natural categories. *Cognitive Psychology, 8,* 382-439.

Schlesinger, M., & Langer, J. (1999). Infants' developing expectations of possible and impossible tool-use events between ages 8 and 12 months. *Developmental Science, 2,* 195-205.

Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought: The insides story. *Cognition, 56,* 129-163.

Spelke, E. S., Breinlinger, K., Macomber, J., Jacobson, K. (1992). Origins of knowledge. *Psychological Review, 99,* 605-632.

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69,* 1-34.

Note:

Preparation of this paper, and some of the research reported on therein, was supported by National Institutes of Health grant R01-HD23922 to Frank Keil and by Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarship (NSERC PGSB-243737-2001) to Marissa Greif