Object perception and object naming in early development

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Among our most fundamental capacities are those that allow us to perceive, categorize and name objects. Recently, controversy has surrounded the question of how young children learn names for objects, in particular, the relative roles of perception and higher-level world knowledge. It is well known that adults depend strongly on conceptual knowledge in a variety of categorization tasks, including object naming. We argue, however, that perception may play a special role in early object naming and, in particular, that certain kinds of world knowledge known to guide adult naming may come to guide naming only rather late in development. Building early mechanisms of naming on a perceptual foundation that may be encapsulated, and thus shut off from more reflective processes, may explain in part why young children can easily and rapidly learn names for things from the adults around them, despite the fact that adults and children may possess very different conceptual organizations.

Among our most fundamental capacities are those that allow us to perceive, categorize and name objects. As adults, we easily perceive both familiar and novel objects as three-dimensional entities with structure, we can usually assign even novel objects to their rough categories (artifact, animal, plant, etc.) and the names for such objects occupy a considerable portion of our active vocabulary. Infants also possess knowledge of objects[1], they can sort objects into categories such as animal and vehicle[2], and some of the earliest words in the young child's vocabulary are names for things. The latter capacity is species-specific: only young humans learn names for objects rapidly and easily during the first few years, and readily generalize these learned names to other objects that are relevantly similar[3].

Despite the ease with which infants and toddlers learn names for things, the nature of the representations underlying object names is complex and not completely understood. All investigators agree that we generalize object names to new instances on the basis of some kind of similarity; yet, there is much debate about the nature of this similarity. What is it that holds things together and affords a set of objects some coherence under a category name?

A broad division between types of similarity is captured by Quine's[4] distinction between 'intuitive' and 'theoretical' similarity. The first is a type of similarity that is easily apparent and engages perceptual systems that provide us with information about shape, size, color, etc. The second is a type of similarity that engages explanatory and/or theoretical concepts in evaluating even fundamental perceptual properties such as size, shape and texture. To illustrate this distinction, Quine gives the example of the marsupial mouse: by intuitive standards, this animal would be grouped with the ordinary mouse because the two look alike; but by theoretical standards, the marsupial mouse would be grouped with kangaroos and opposums (and not the ordinary mouse). The different groupings of the marsupial mouse depend on evaluating its properties using different metrics.

Which kind of similarity best captures our representations of object names? The answer may differ, depending on both task and maturity. In general, recent investigations have confirmed that conceptual or explanatory context does play an important role in people's categorization of named objects[5]. For example, Rips[6] asked adults to imagine a round object whose size was just halfway between the largest example of an American quarter and the smallest example of a pizza. Then he asked them to judge the likelihood of it being a quarter or a pizza. People judged it more likely to be a pizza, presumably because they know that monetary systems do not permit a range in the sizes of a single value coin; in contrast, there is no such constraint on the sizes of pizzas. Among preschool-aged children, Keil[7] has shown a similar pattern, that is, strong effects of knowledge of higher-level categories on inferences about individual exemplars. Preschool-aged children were shown an ambiguously drawn object and heard it described either as 'my hyrax – it is a kind of animal' or 'my hyrax – it is a kind of rock'. In the first case, the children generalized the term 'hyrax' to objects of the same shape, regardless of their surface texture or color. In the second case, children generalized the term to

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objects of the same texture or color, regardless of their shape. Thus, from at least four years of age, children use their knowledge of an object's global category (animal versus rock) to evaluate the relative importance of its perceptual properties, indicating the importance of conceptual context.

These findings indicate that conceptual knowledge plays an important role in how we generalize an object's name. But they also suggest that our patterns of generalization will depend very much on how rich our knowledge is about a given category of objects. In turn, this raises a problem for the very early acquisition of object names: if young children have less knowledge or different knowledge about object categories compared with the adults around them, then they might evaluate the importance of specific properties differently from those of adults. Using Quine's example, very young children might call both the marsupial mouse and the ordinary mouse by the same name (mouse) by virtue of their perceptual similarity, but older children and adults might qualify this by adding 'it is not really a mouse' or 'they are not the same kind of mouse'.

In recent investigations, we have tested the relative roles of perception and conceptual knowledge in young children's object naming. A wide range of studies has shown that young children (from ages two to five) tend to generalize a novel object's name to new objects that have the same shape as the one they originally heard labeled, even if it is quite different in texture or size[8–11]. This pattern holds for novel objects that appear to be artifacts, and also for novel objects that possess 'eyes' and hence appear to represent animate objects[12]. The pattern is consistent with many other findings on early word learning and object categorization, which suggest that infants and young children tend to represent as categories those objects that adults judge to belong to the same taxonomic category; for example, different kinds of animals and vehicles[2,13]. Because objects that have the same or similar shapes often belong to the same taxonomic or 'kind' category, infants and children could use shape similarity to identify members of a given category, even if they have relatively little specific knowledge about the category. Later, these categories could be enriched by the acquisition of more specific knowledge. Alternatively, children could start with relatively rich ideas about the nature and structure of different kinds of categories, and shape similarity might then be just one among many kinds of similarity that children use to unite category members.

Strong versions of these two possibilities form the ends of a continuum (see Box 1). Each involves quite a different view of what kinds of knowledge young children have, how this interacts with perception and how perception and knowledge jointly enter into children's earliest naming. At one end of the continuum, one might assume that shape similarity is both necessary and sufficient for identifying members of a category. In this view, shape would play a key role in the earliest learning of object names, specifically, by allowing children to identify category members in the absence of dense knowledge about the category. According to this view, shape similarity would also completely and exhaustively describe the 'meaning' underlying an object's name: children would believe that an object name refers to a category of things for which shape similarity is both necessary and sufficient. This seems unlikely, for reasons outlined in Box 1. A second, more plausible version of the strong shape view would take shape similarity to constitute a critical bootstrapping device operating to initiate learning in children. At the other end of the continuum, one might assume that children start out with an assumption that object names are cover terms for 'object kinds' and, further, that they possess relatively rich knowledge about the kinds of object categories that are encoded by object names. In this view, shape would be merely a superficial 'symptom' that should be abandoned whenever alternative bases for categorization are available. The first view predicts that young children should show a strong bias to generalize object names on the basis of shape, even in the presence of additional knowledge. The second predicts that young children should generalize on the basis of shape only as a default; if additional relevant knowledge is available to the child, then it should overcome any preference for shape.

What role does specific world knowledge play in the earliest learning of object names? One case that we have studied concerns names for common artifacts. Many investigators have noted that, for adults, a critical criterion for deciding on an artifact's category (hence what it is called) is its function[14]. Although function is not the defining criterion for artifacts[15], adults do consider it to be more important than overall appearance when making simple category judgments[16]. Recent research suggests that this functional importance may have a neural correlate. When adults name either animals or tools, both right and left ventral temporal lobes are activated. However, there are also differences in activation during naming of things in the two categories: when adults name animals, there is also selective activation of the left medial occipital lobe (an area of the brain involved in early visual processing), whereas, when they name tools, there is activation of the left premotor area, specifically, a region that is activated when subjects imagine hand movements[17]. Thus, there is considerable evidence that functional properties of artifacts matter when adults name artifacts.

We have found, however, that the pattern of naming among young children is quite different, suggesting that the mechanisms underlying very early object naming may change substantially during development. In a number of experiments, we have explicitly instructed young children and adults about the functions of novel objects, and then asked them either to generalize the object's name to other novel objects, or to judge the capability of other objects to carry out the designated function. We have compared these responses to those of subjects who only heard the objects named, but did not see or hear the function described. Over a range of experiments, we have found that although young children are quite capable of understanding some aspects of an object's functional capabilities, this understanding does not appear to enter into their generalization of object names[18–20]. In contrast, adults consistently incorporate functional information into their object naming[18,19].

In one experiment, we showed three-year-olds, five-year-olds and adults a novel object and named it with a novel noun (for example, 'This is a dax'). Half of these subjects were then also shown the object's function. One object was made of sponge, and its designated function was to

Box 1. Perception and conception in early object naming

Positions regarding the importance of shape in early object naming form a continuum that engages several important theoretical questions about the relationships among perception, higher-level conceptual knowledge and naming in both children and adults. The strongest possible position regarding the importance of shape in object naming would amount to the claim that similarity of shape is both necessary and sufficient for membership in a named object category. This claim has been falsified by numerous logical arguments, as well as experimental results showing that even relatively simple concepts cannot be adequately described as combinations of necessary and sufficient properties[a,b,c]. Although the evidence suggests that young children preferentially generalize object names to objects with similar shapes, it is unclear at the moment whether this constitutes their complete entries for these terms. Given the force of logical arguments, however, it seems unlikely that the full meanings of object names are characterized by a description of the shapes of their category members.

At the other end of the continuum, a different strong view posits that young children start out by assuming that object names are cover terms for objects of 'like kind'[d–f]. This view assumes that 'like kind' constitutes the necessary and sufficient conditions for category membership. It links the naming capacity in infants and young children to that of adults, by positing that all humans make a unified assumption about the nature of object names. Such a fundamental similarity among the representations of infants, young children and adults would predict that both child and adult will have the same 'kind' in mind when labeling objects. What this view omits, however, is some mechanism for determining what constitutes 'same kind'. Given putative large differences in the conceptual organizations of child and adult[g], it seems unlikely that exactly the same kinds are represented by both learner and adult.

A third view, which we endorse, takes shape similarity to be critical to early object naming by providing the initial mechanisms for generalizing object names to new objects. Our view holds that, however the meanings underlying object names are ultimately characterized, shape similarity constitutes a critical bootstrapping mechanism operating to initiate learning of object names in young children by allowing them to identify category members in the absence of dense knowledge about the category. That is, whether children do or do not assume that names are cover terms for 'like kind', they can use shape similarity to gain an initial entry to the category. Once they have this toehold, they can use their representations to test the limits of its truth, by using information such as the patterns of naming distributed across exemplars[h], explicit instruction[i] and assumptions about conceptual coherence[j]. To the extent that perception of invariant shape provides a simple and direct link to object naming, young children may begin learning object names, which then might form the basis for the more complex contents of adult meanings. The evidence we present in this review suggests that young children generalize object names on the basis of shape even when that information is challenged by additional salient functional information, and even when this functional information is accessible to the same-age children in other contexts. These results form the basis for our hypothesis that object naming may be initially 'encapsulated' or shut off from more reflective processes that permit us to consider the relevance of many different kinds of properties for an object's membership in a named category. Such a complex and multifaceted system clearly underlies both object naming and other categorization activities in adults[j], but it may emerge as a second step in the development of naming.

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mop up water. A second object (named a 'rif') was made of cork, and its designated function was to hold stick pins (see Fig. 1). As subjects saw a demonstration of the object's function, they heard a description, such as: 'This is a dax (rif). Daxes (rifs) are made by a special company just so they can mop up water (hold stick pins)'. After hearing the novel object named (and, if appropriate, seeing and hearing about its function), subjects were shown four new objects for each of the originals and were asked whether each was a dax. Half of the objects had the same shape as the original one, but could not support its function because they were made of inappropriate material. The remaining half had different shapes from the original, but were made of the same material, and hence could support the specified function (see Fig. 1A). Children and adults who heard the object named but did not hear the instruction about function generalized on the basis of 'same shape', consistent with previous reports (see Fig. 1B. Furthermore, three-year-olds who heard the object named and did hear about function also generalized by shape, indicating that the functional information did not enter into their naming judgments. In contrast, adults who heard the function instructions generalized entirely by material, accepting only objects that could support the designated function, even if they were radically different in shape. Five-year-olds who were instructed about function generalized the name sometimes on the basis of shape and sometimes on the basis of material (see Fig. 1C), suggesting significant development between age three and five, and from age five to adulthood.

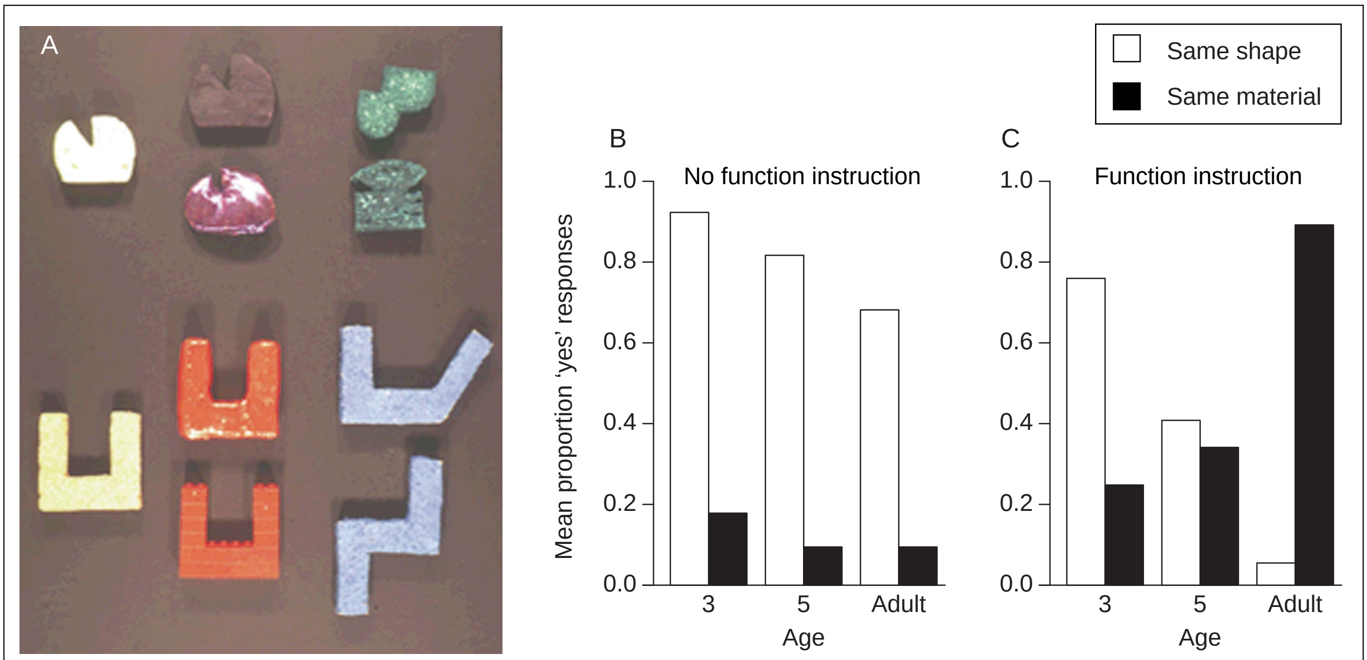

Fig. 1 Contrasting the use of shape versus function information in the generalization of a novel object's name. (A) Each of the two object sets contained an original object (left), which subjects observed while they heard it labeled with a novel name. In the top set, the object was made of sponge, and its designated function was to wipe up water. In the bottom set, the object was made of cork, and its designated function was to hold stick pins. All subjects were then asked to generalize the object's name to four new objects (shown to the right of the original). Half were the same shape as the original, but were made of materials that could not support the designated function. The remaining half were made of the same material as the original (hence they could support the function), but were of different shapes from the original. Half of the subjects were not instructed about the object's designated function **(B)** and half were so instructed **(C)**. The results are presented separately for each subject group. Three-year-olds generalized strongly on the basis of the shape whether or not they had been instructed about the objects' function. Adults who had not been instructed about function also generalized strongly on the basis of shape. However, adults who had been instructed about the function generalized strongly on the basis of material, that is, the property that could support the designated function. Five-year olds showed an intermediate pattern, in which their generalization was weakly modulated by instructions about function. This pattern of results held over several experiments.

Separate questioning of the same subjects showed that even the children understood that shape was less relevant than material in carrying out the designated function. When asked: 'Could this (test object) wipe up water (hold stick pins)?' children responded on the basis of material, not shape. However, there was also quite substantial development in how well the children understood this. Only about two-thirds of the three-year-olds generalized on the basis of material, whereas all of the five-year-olds and adults did so. Thus, three-year-olds showed relatively weak understanding of function, whereas five-year-olds and adults showed quite robust understanding.

Although these results suggest that function does not enter into naming, the objects used in the first experiment were simple geometric shapes with functions that might have been unfamiliar to young children. Therefore, a second experiment was conducted in which the novel objects were similar to familiar objects, and were specifically designed to support functions known to be understood by very young children (Ref. 21; and V. Kolstad and R. Baillargeon, unpublished). One object was a container of an unusual shape, designed to hold water, and the second was a rigid cane, designed to retrieve objects from a short distance away. Following the procedures for the first experiment, two-year-olds, three-year-olds, five-year-olds and adults either heard the object's name with no instruction about function, or they heard the name together with instruction and a demonstration of what the object could do. Then they were asked whether the name applied to additional novel objects: half of these had the same shape as the original (but could not support the function) and half could support the same function as the original (but had a different shape). After the entire procedure, all subjects were also asked to decide whether each object could carry out the designated function. The results of the 'name question' showed that two- and three-year-olds generalized the object name on the basis of shape, whether or not they had been instructed about function (see Fig. 2A). Five-year-olds generalized relatively weakly on same shape (but not strongly on same function) and, again, there was no difference as a result of instruction about function. Adults, in contrast, generalized the name strongly by shape when they had no information about function, but by functional properties (material, solidity, overall length, etc.) when given such information (see Fig. 2B). Thus, as in the first experiment, the youngest children were not affected by instruction – generalizing by shape regardless of instruction – whereas the adults were strongly affected by instruction.

In contrast to the results of the 'name question', the results of the 'function question' showed that none of the children or adults generalized strongly on the basis of same shape. However, as in the first experiment, there was a clear development in children's understanding of the functions, with increasing generalizing on the basis of properties relevant to function with age. Three-year-olds showed some understanding of which objects could carry out the designated functions (generalizing somewhat more to same-function objects than to same-shape objects), whereas five-year-olds and adults showed robust understanding, generalizing strongly to same-function objects (see Fig. 2C). Thus, the results of the 'function question' confirm an increase in children's explicit understanding of function.

A final experiment examined whether the same pattern would hold for familiar objects. Two-year-olds, three-year-olds, five-year-olds and adults were shown a comb and a clothes-pin, they heard them named and then participated in using them in functionally appropriate ways. Subsequently, they were asked to generalize the names 'comb' and 'clothes-pin' to new objects, half of which were the same shape (but could not carry out the function, for example, a cut-out paper comb, a soft clay clothes-pin) and half of which were capable of supporting the function (but had a very different shape, for example, a toy rake, a metal clamp). A second group of subjects did not hear the objects named, but only observed the function; these subjects were then asked which of the test objects could also carry out the function. Children and adults who were asked to generalize the object's name did so on the basis of shape, generalizing the name 'comb' to objects of the same shape as the original comb, but made of thin paper, soft clay, etc. In contrast, children and adults who were asked which objects could carry out the designated function selected the objects that could, indeed, carry out the function – those that had a different shape from the original comb or clothes-pin.

These results suggest that object naming among young children, that is, the answer to the question 'Is this an X?', might be cut off from general world knowledge, and that much of this specific knowledge might be incorporated rather slowly. It is important to note that this is not exclusively a result of relatively impoverished understanding of function among children, although their understanding clearly does grow substantially over the early years (D. Kelemen, PhD Thesis, University of Arizona, 1995; D. Matan, PhD Thesis, MIT, 1996). In our studies, children who were queried directly about function understood that shape was not necessarily relevant to the objects' functions, and that other properties – such as material, rigidity and overall length – were relevant. Yet, this knowledge did not appear to influence their generalization of the objects' names. Recent studies indicate that young children can generalize a novel object's name on the basis of its function, but that this may require special circumstances in which the function is made highly salient and demonstrated repeatedly in the context of naming[22]. In contrast, adults appear readily to incorporate functional information in object naming for novel objects, and they include both shape and functional information for familiar objects.

The notion that object shape may play a special role in early object naming may seem at odds with our understanding of the true nature of object names as cover terms for object kinds. Many have noted that object names, because they are cover terms for kinds, engage rich representations of object categories that can support inductive inferences[23,24]. For example, our knowledge of things called 'dog' or 'cup' is a great deal richer than shape alone; therefore, shape similarity may be a relatively unimportant (even misleading) criterion for deciding whether a new object should be called 'dog' or 'cup'. More generally, our knowledge of natural kind categories (such as dog, tree, rock, etc.) may rest upon foundational beliefs which specify that each such

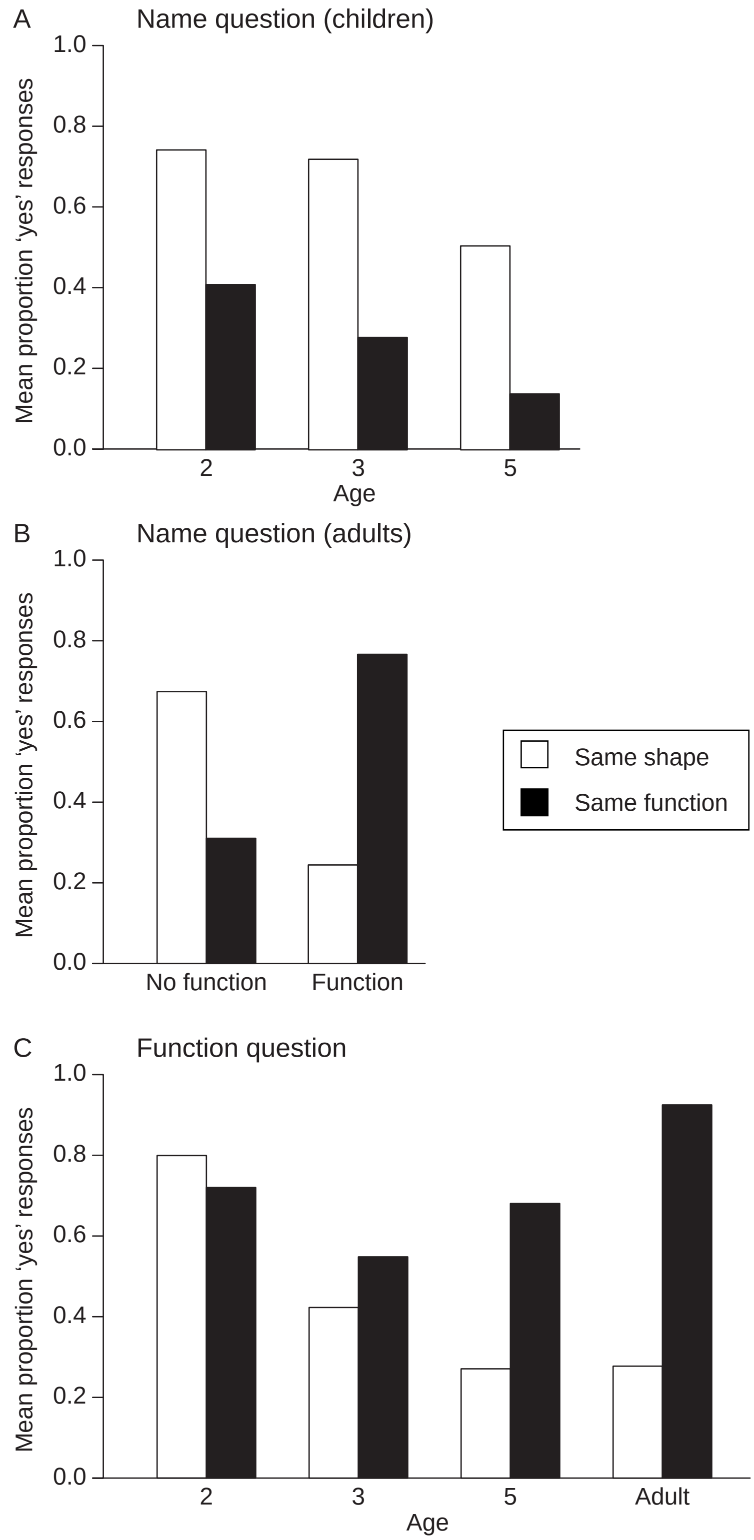

Fig. 2 Results of a shape versus function experiment using objects whose shapes and functions were similar to familiar objects. Two-year-olds, three-year-olds, five-year-olds and adults heard the novel object's name; half were also shown and told about the object's designated function. Subjects then were shown test objects and were asked to generalize the novel name to the test objects ('name question') as well as to judge whether each object could carry out the designated function ('function question'). In the 'name question', children generalized on the basis of shape whether instructed about function or not **(A)** (No function and function data collapsed). In contrast, adults who were not instructed about function generalized on the basis of shape, but those who were instructed generalized on the basis of functionally relevant properties **(B)**. Responses to the 'function question' were not made on the basis of shape, but rather, on the basis of functional properties **(C)** for all except two-year-olds, who generalized on both shape and function. This suggests that functional information is accessible to young children, but is not readily integrated into naming.

Outstanding questions

- What kinds of learning mechanisms might lead young children to incorporate functional information into their naming generalization? What kinds of conceptual reorganization might do the same?
- Is a shape bias likely to be as strong for natural kind objects (such as animals and plants) as it is for artifacts? Why is this so (or not so)?
- Many object categories range over sets of objects that need not share shape similarity. Given a strong initial shape bias, how might children learn that object names can range over such sets?
- Why might children and adults be willing to generalize an object's name to representational versions of the object (such as a toy comb or a large sculpture of a clothes-pin)?
- What different conclusions about the underlying cognitive architecture would we reach under a 'strong' versus 'weak' interpretation of the 'shape bias' results for naming?
- What changes in the patterns of neural activation might be expected during development if there is a genuine change towards incorporating functional information into object naming?

category has some 'essence' – that which truly makes a dog a dog, or a rock a rock[25]. The contents of this essence include biological knowledge, which is known to develop well past early childhood[26]. Similar arguments hold for artifact categories. Specifically, some have considered the intention of an artifact's creator to be the most important criterion for category membership[14], over and above any perceptual or functional properties.

How might these theoretical notions be reconciled with the existence of a powerful bias to generalize object names on the basis of shape similarity? A likely possiblity is that the mechanisms underlying early object naming, while very simple, may serve as a bootstrapping device for the initial development of naming. Object perception – specifically, perception of objects in terms of their invariant shapes – has many characteristics that suggest its suitability for such a role. It is well known that adult object recognition engages perception of object shape, in preference to other properties such as the object's size or surface properties[27]. Perceiving an object's shape is a speciality of the human visual system, it is available to all learners regardless of mental or social endowment, and the same system is available to learners and the adults around them who name things for their young. Unlike our rich conceptual systems, which undergo significant conceptual change[28], the perception of shape similarity is unlikely to undergo radical developmental change. This equity between child learner and adult tutor allows object names to be learned, even if the concepts behind these object names are quite different.

It still remains a challenge to discover the entire set of circumstances under which object shape will be critical for object naming, and those in which it is by-passed in favor of other kinds of properties – perhaps quite subtle properties or combinations of properties whose use entails the existence of complex conceptual structures. What does seem clear, however, is that a sensitivity to similarities among objects in terms of their invariant shapes may play a critical role in starting the learning process.

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