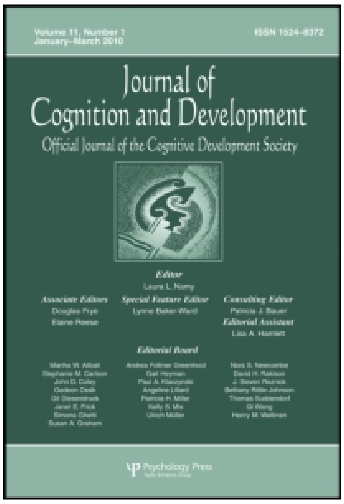

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FEATURE ARTICLE

Perceptual and Conceptual Processes in Infancy

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It is suggested that we must distinguish 2 types of object categorization in infancy. One is perceptual categorization, which is an automatic part of perceptual processing that computes the perceptual similarity of one object to another. It creates perceptual schemas of what objects look like. The other is conceptual categorization, which is based on what objects do. It consists of the redescription of perceptual information into conceptual form, particularly the paths that objects take and the interactions among them. This process creates the notion of kinds, such as animals, plants, vehicles, and furniture. The similarity in this kind of categorization is of roles in events, not the physical appearance of the objects. Several differences between the 2 types of categories are discussed, of which the most important is the different functions they serve. Perceptual categories are used for object identification; conceptual categories control inductive inference. Experimental results are described showing that because early conceptual categories tend to be global in scope, the inductive generalizations based on them are global in scope as well.

One of the enduring mysteries of the mind is how we begin to form concepts that take us beyond the information provided by our senses. Once a conceptual base is established it is not so difficult to see how it influences the way we perceive the

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world, but the great question is how concepts are formed in the first place. For example, when and how do infants come to develop the concept of dog or the concept of animal, and what do these concepts first consist of? At the least, to form these concepts requires the ability to categorize dogs or animals as alike in some way. There has been a lively research tradition on how infants begin to categorize. Infants as young as 3 months of age categorize pictures of dogs as different from cats (Quinn, Eimas, & Rosenkrantz, 1993) and horses as different from zebras (Eimas & Quinn, 1994). Quinn and Eimas (1996) found that the early categorization of dogs and cats is primarily based on differences in their facial features rather than overall appearance. This work, along with that of Mareschal, French, and Quinn (1998), also showed that there are some asymmetries in the learning of these two categories, in part because of the greater variability in dogs' facial features. Other research has shown that infants between 4 and 10 months gradually become sensitive to the correlated attribute structure that characterizes the appearance of animals and also of faces (Younger, 1992; Younger & Cohen, 1986). These studies have given us considerable insight into the nature of infants' perceptual categories.

These studies used pictures of real objects or of artificial stimuli and some version of the habituation–dishabituation method, for example, familiarization followed by preferential looking. A typical design is to present a series of exemplars from one category and then to pair a new exemplar from the familiarized category with an exemplar from a new category. Longer looking at the new category exemplar is taken to indicate categorization. The technique has been a rich source of information about categorization but is less informative about how infants conceptualize the stimuli they are looking at. For example, infants can discriminate between pictures of dogs and cats, but do they know what dogs and cats are? And if so, exactly what have they learned about these kinds of animals?

The traditional view is that these perceptual categories of dogs, cats, and so forth, are the foundation on which concept formation builds. Infants are said to learn first about individual instances, such as one or more individual dogs, from which they generalize to dogs as a class by basic-level processes of categorization. That is, they first learn to identify what dogs look like and then to associate various behaviors and other properties with these perceptual categories. With experience they are able to generalize from dogs to cats and other perceptually different creatures to construct a more general category of animal. Thus, conceptual development is assumed to begin at a concrete level and then gradually become more abstract, as children learn to generalize across more and more varied instances (Madole & Oakes, 1999). Hence, in this view the first concepts are associative packages at the basic level (Eimas, 1994; Mervis & Rosch, 1981).

In the last few years, McDonough and I have been using a different technique to study the nature of these early concepts. We have been exploring the associative generalizations that infants make about objects such as dogs and cats by having them imitate simple events using little models of the real objects (Mandler &

McDonough, 1996a, 1998b; McDonough & Mandler, 1998). This work on inductive inference, which is described later in this article, in conjunction with our work on categorization using the object examination test (Mandler & McDonough, 1993, 1998a), has led us to the conclusion that infants are developing concepts from an early age, but that these tend to be abstract and global in nature rather than basic level. An attempt to reconcile our data with the extensive research showing the early ability to categorize animals and other objects at the basic level (e.g., Cohen & Younger, 1983; Reznick & Kagan, 1983) has led us to conclude that there are two rather different processes in infant cognition, both of which can be at work in similar tasks; namely, perceptual and conceptual categorization. One of these kinds of categorization leads to the ability to recognize objects such as dogs and the other provides their meaning. This article attempts to explicate these two types of categorization and to show some of the differences between them. After defining the two kinds of categorization under consideration, evidence for each is presented. Then I discuss how conceptual categorization might come about and how it can account for the data showing that global conceptual categories control inductive generalizations and associations in infancy. Finally, I summarize the differences between perceptual and conceptual categorization.

THERE IS MORE THAN ONE KIND OF CATEGORIZATION

Although a number of researchers have proposed that there is more than one kind of categorization in infancy (e.g., Bornstein, 1984), this view has not been without criticism. It has been suggested by some that infants in the first year are too young to have developed conceptual categories, and during this period they must rely solely on perceptual processes (Haith & Benson, 1998). It has also been suggested that ascribing more than one kind of categorization in infancy is unparsimonious, because conceptual processing is “special-purpose” processing being called on in an ad hoc fashion (Quinn & Eimas, 1997), and because conceptualization is too indirectly tied to the data and too difficult to study in infancy (Haith & Benson, 1998). However, I hope to show that positing more than one kind of processing in infancy is neither ad hoc nor unparsimonious, but instead is necessary to explain the existing data. Whenever parsimony is invoked, one must ask, parsimonious with respect to what? Is it parsimonious with respect to categorization tasks alone or to understanding the whole range of infant behavior, such as the way in which infants form associations and make inferences? Although it may be easy to account for the data from a given categorization experiment by calling on perceptual factors alone, we want to be able to account for other aspects of cognition as well. If we accept only perceptual explanations, then how do we account for the development of thought? We cannot just ignore the beginnings of conceptual inference (McDonough &

Mandler, 1998), problem solving (Willatts, 1990), or recall of the past (Bauer & Mandler, 1992; Mandler & McDonough, 1995; Meltzoff, 1988). We must explain what the conceptual system is like such that infants can carry out these kinds of thought processes. Furthermore, when explanations for infant cognition are couched only in perceptual terms, the resulting theory itself becomes unparsimonious if it requires increasing elaboration to account for data that implicate conceptual functioning. Thinking is not the same as seeing, and if we try to make them the same or ignore one altogether, we are in danger of distorting our understanding of both kinds of processes.

The traditional view that infants categorize objects solely in terms of their perceptual appearance requires a transition either at the end of infancy or in early childhood from perceptually based to conceptually based categorization (Keil, 1991). The infant or young child must progress from categorizing a set of objects as all looking similar (e.g., all having curvilinear shapes or rough textures or moving in the same way) to categorizing the same set as the same kind of thing (e.g., animals, or perhaps things that eat and sleep). However, no one has ever offered a satisfactory account of how or when such a transition might take place. I argue in what follows that the failure to document this transition is due to the fact that it does not occur. Conceptual categorization begins early in life and does not consist of adding conceptual information onto perceptual categories; although based on perceptual information, it is conceptually based from the outset.

Categorization can take many different forms. One can categorize holistically not only on the basis of overall similarity of appearance or on the basis of conceptual kind, but also on individual properties such as color or shape (Bruner, Goodnow, & Austin, 1956), location (Mandler, Fivush, & Reznick, 1987), and even on ad hoc, arbitrary bases (Barsalou, 1983). Many of the arguments over the role of perceptual similarity in categorization are exacerbated because theorists study different kinds of categorical processing without specifying the kind of categorization they have in mind. Psychologists usually talk about concepts, but they often study perceptual categorization. Hence, we find research on disease symptoms (Nosofsky, Kruschke, & McKinley, 1992), random dot patterns (Posner & Keele, 1968), natural kinds and artifacts (Smith & Osherson, 1988), and geometric forms (Medin & Schaffer, 1978) all being used to test competing models. There seems to be a common assumption that categorization is categorization is categorization. However, it does not seem reasonable to talk about categorization pure and simple. Although similar processes are likely to be involved in all forms of categorization, there are enough differences in the nature of the input, the cognitive structures that result, and the purposes to which different kinds of categories are put, to warrant a close examination of the different forms.

Informally, the contrast between perceptual and conceptual categorization can be characterized as that between knowing what something looks like and knowing what something is. The division means that infants can have a perceptual category of widgets that enables them to recognize a widget when they see one (even when they have no idea what a widget is); they might or might not also formulate a concept of a widget that provides its meaning. As we will see, when they do form a conceptual category that provides the meaning of widgets, it is apt to be much broader than the perceptual category itself. Although this contrast can be made throughout life, infant studies are particularly useful in differentiating the two types of categories because they are easier to separate early in development. As experience with the world proceeds, the two types become increasingly linked, which blurs their fundamental differences. Eventually, most perceptual categories end up having a coextensive concept. This linkage is part of the reason, I believe, for the lack of differentiation between perceptual and conceptual categorization in much of the psychological literature. Another reason is a failure to distinguish between the automatic unconscious processes involved in forming perceptual prototypes and the conscious classification processes typically involved in sorting tasks and other research on older children's and adults' concepts.

The kind of perceptual categorization I address in this article takes place without awareness merely as a result of exposure to visual stimuli. It is concerned with the physical appearance of things (what dogs, tables, faces, and even random dot patterns look like). Given a series of stimuli that bear some physical resemblance to each other, the perceptual system abstracts the principal components of the presented information (e.g., Posner & Keele, 1968), and this influences recognition of similar stimuli at a later time. It can be characterized as learning a perceptual prototype or a perceptual schema. This kind of categorization is part of the visual input system, and is modular in Fodor's (1983) sense of the word. It is domain specific, mandatory, and there is limited central access to the information it is using; that is, the information is not accessible to consciousness (Moscovitch, Goshen-Gottstein, & Vriezen, 1994). The implicit nature of the information can be illustrated by the perceptual categorization of faces into male and female. We all do this easily and have since about 5 to 6 months of age (Fagan & Singer, 1979), but we do not know the information that we use to represent the two kinds of faces (indeed, the information being used is still not well understood; Abdi, Valentin, Edelman, & O'Toole, 1995).

Infants as young as 3 months of age form perceptual prototypes of objects in roughly the same fashion as adults (Bomba & Siqueland, 1983; DeHaan, Johnson, Mauer, & Perrett, 1999). The fact of prototyping does not in itself require a particular kind of representation, as perceptual prototypes can be holistic or feature based (Armstrong, Gleitman, & Gleitman, 1983). In either case the perceptual system is pulling out the main factors or principal components of the patterns being presented. One example of how such a system might work is the connectionist model proposed by McClelland and Rumelhart (1985), in which prototypes are formed by summing connection strengths across individual events while retaining some information about individual exemplars. Crucially, forming these kinds of perceptual categories or prototypes occurs without attention or intention and does not require conceptualization.

Conceptual categorization, on the other hand, is concerned with setting up kinds, that is, with formulating what sorts of things dogs or tables are (Gelman & Wellman, 1991). This is a fundamental human capacity that differs from the ability to tell one thing apart from another. The process is one that constructs concepts, and for infants it is part of creating a central, accessible representational system (Mandler, 1988, 1992). That is, concepts, as I am using the term, begin to be formed from attentive, conscious analysis of what is being perceived. As adults we do our conscious thinking, planning, and problem solving with the large repertoire of concepts we have built up over the years. However, infants face the task of getting this repertoire started. As they begin to encounter animals, vehicles, furniture, utensils, and so forth, they must form some idea of the meaning of these things, in particular characterizing the roles they play in events. The core of concept construction insofar as objects are concerned is characterizing what they do or what is done to them.

Representing events is almost always more abstract than representing what an object looks like, because events involve relations among objects. These relations are often functional in nature (Nelson, 1974a, 1985) but early in infancy must be understood in an even more abstract way. For example, infants are apt to notice the fact of a contingency when a person picks up an object before they understand the function the person is accomplishing. This characteristic of early object concepts means that the traditional view that concepts develop from the concrete to the abstract has it the wrong way around (Keil, 1998; Simons & Keil, 1995). Early concepts about objects are abstract—or general and vague, if you will—because their content applies to large domains. For example, if as I have suggested (Mandler, 1992), infants understand animals as self-movers that interact contingently with other objects, this characterization is true for animals in general, not just specific kinds of animals.[1]

I am restricting discussion of categories to objects rather than to features or dimensions for two reasons. First, it seems highly likely that the first conceptual categories have to do with objects rather than their parts or features. Infants use features such as eyes to identify an object as an animal, but such features do not seem to be crucial for them in determining the meaning of *animal*. Second, categorization of object features as entities in their own right may always be a conceptual construction, in the sense that it requires conscious analysis and extraction of parts from a whole (as I describe later, it requires perceptual analysis), which is different

[1]I refer of course to infants' representations of kinds (or to use John Locke's terminology, nominal essences, not real essences). My concern is with what infants consider an animal to be, not with what an animal actually is.

from the automatic and unconscious processing that is sufficient to enable perceptual categorization of objects.

SOME CONTRASTS BETWEEN PERCEPTUAL AND CONCEPTUAL CATEGORIES

The textbook view of the categorization of objects is that it begins at the basic level (e.g., Bjorklund, 1995).[2] The position is sometimes modified by the qualification that children's basic-level concepts may differ from those of adults' (Mervis & Mervis, 1982), but because no criteria have been offered to delimit the notion of child basic, it has unfortunately tended to become a synonym for whatever children categorize. In any case, if one is going to make a claim about the first concepts to be formed, then it is important to begin at the beginning and study infants. However, at the time Rosch and Mervis (1975) proposed their theory there were almost no developmental data of any kind contrasting basic-level and superordinate categorization and virtually no research conducted with either very young children or infants. Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) conducted two developmental studies on children 3 years and older. In one of these experiments they asked children to sort items into either basic-level or superordinate categories of clothing, furniture, and vehicles. The results indicated that even in the first grade, children had difficulty doing superordinate classification in spite of the fact that the items they had trouble classifying were among those most frequently found in the category generation norms of grade school children (Posnansky, 1978) and even in those of 5-year-olds (Nelson, 1974b). Because children spontaneously generate these items to the superordinate name, it suggests there was a problem with the sorting task itself. I discussed elsewhere (Mandler, 1997) the difficulties with this and the other task they used (matching-to-sample) and only want to point out here the importance of unconfounding levels when making comparisons of categorization at different levels. If one wants to discover whether basic-level categorization is easier than superordinate categorization, one should not contrast sorting of shirts, chairs, and cars with sorting of clothing, furniture, and vehicles (Mandler, Bauer, & McDonough, 1991). Shirts, chairs, and cars may indeed represent basic-level categories, but they also represent superordinate contrasts. If children do well, one has no way of telling whether they are using the within-category similarity of the basic-level contrast or the between-category dissimilarity of the superordinate contrast,

[2]There have been many debates over the status and meaning of the term *basic level.* They illustrate the difficulties that arise when categorizing on the basis of physical appearance and categorizing on the basis of conceptual kind are not differentiated (see Mandler, 1997, for discussion). Rosch and Mervis (1975), like most other psychologists, did not make this distinction when they invented the term.

or most likely both. To test basic-level categorization one must contrast shirts with pants, not shirts with cars. Unfortunately, this confounding of basic-level and superordinate information has been the usual case in sorting studies (Daehler, Lonardo, & Bukatko, 1979; Mervis & Crisafi, 1982; Saxby & Anglin, 1983).

Sorting tasks are too difficult for young children, and virtually impossible to conduct with children too young to understand instructions. Riciutti (1965) devised a sequential touching task that is a simplified version of the sorting task adapted for 1- to 2-year-olds. Objects from two contrasting categories are placed in front of the child, and the child is encouraged to interact with them. No labeling is used and the order in which the objects are touched is measured. Riciutti used only identical geometric forms, but Nelson (1973) and Sugarman (1983) modified the task to include varied and realistic objects. This set the stage for using the task to study basic-level and superordinate categories. In Mandler and Bauer (1988) and Mandler et al. (1991), we used little models of real-world objects and measured runs of within-category touches compared to those expected by chance. We found clear-cut categorization of the superordinate classes of animals, vehicles, plants, furniture, and eating utensils by 1½- and 2-year-old children. On the other hand, they showed little basic-level categorization; for example, even at 2 years they did not respond differentially to dogs and rabbits, cars and motorcycles, trees and cacti, tables and chairs, or spoons and forks. The only subcategorization we found in these experiments was at the life-form level for animals (dogs vs. birds or fish) and at a similar level for vehicles (cars vs. airplanes). These data do not support the notion that basic-level concepts are the first to be formed.

Rosch and her colleagues meant the term *basic-level* to refer to concepts (Mervis & Rosch, 1981), but they tended to rely on measures that depend on physical appearance (listing properties of objects, forming images of them, speed of identifying them, etc.; Rosch et al., 1976). Perhaps what they were measuring was some important level of perceptual categorization, a level at which it might be especially easy to form a perceptual prototype, as defined at the beginning of this article. It might be in this sense that basic-level perceptual categories are the first to be formed. This interesting proposition has never been tested, because no comparisons of infants' rate of learning perceptual categories at the superordinate, basic, and subordinate levels have yet been carried out. As mentioned earlier, when 3- and 6-month-olds are shown as few as 12 pictures of horses, they form a perceptual category of horses (or perhaps more accurately, horse patterns) that excludes zebras and giraffes. When shown pictures of cats, they form a perceptual category of cats (or cat patterns) that at 3 months excludes tigers and at 6 months also excludes female lions (Eimas & Quinn, 1994). Three-month-olds can also form a perceptual category of pictures of tables that excludes couches and chairs (Behl-Chadha, 1996). Such data indicate that 3-month-olds are already proficient perceptual categorizers. At the same time, there are simply no data to tell us whether these categorical feats could also be carried out at the subordinate level. Perhaps infants can form a perceptual category of poodles that excludes dachshunds as easily as they form a category of dogs that excludes cats. The perceptual differences between pictures of these subordinate categories seem just as great as between pictures of cats and lions. Similarly, infants might be able to categorize rocking chairs versus easy chairs as easily as tables versus chairs.

Whether or not perceptual categorization can take place as rapidly at the subordinate as at the basic level in early infancy, there is some indication that it is more difficult for 3-month-olds (and even for older infants) to form perceptual categories at higher levels, particularly at the superordinate level. Behl-Chadha (1996) was unable to show categorization of pictures of furniture as different from vehicles, using the same familiarization and preferential looking technique with 3-month-olds. She did find a category of four-legged mammals that excluded birds and cars, but she used more familiarization trials than for the previous basic-level and furniture–vehicle comparisons, and because of stimulus preference the mammal category did not conclusively exclude fish or furniture. Furthermore, there is quite a bit of overlap in shape at the level of mammals, and she did not test the domain-level category of animals (i.e., including mammals, fish, and birds), which has a greater degree of perceptual variation. One of Rosch's contributions was to show that there is relatively little overlap in shapes at the superordinate level, and shape is apt to be important whenever pictures are categorized (Rosch et al., 1976). In our laboratory, using the picture familiarization and preferential looking technique to study 11-month-olds, we were unable to find differentiation of animals (including mammals, fish, and birds) from vehicles, or clothes from furniture when we made the overall shapes of the test items similar (unpublished data, discussed in Mandler & McDonough, 1993). Similarly, Roberts and Cuff (1989), also using pictures, did not find global categorization of animals in 9- and 12-month-olds.

Recently, Quinn and Johnson (1998) reported that 2-month-olds categorize pictures of mammals as different from furniture but do not differentiate cats from other mammals. They suggested that there may be a trend from global categorization to basic-level categorization in all perceptual learning. This view fits the description of perceptual learning given at the beginning of this article, namely, that principal components are extracted first. Thus, any feature that uniquely divides a stimulus set into two classes (e.g., faces in the mammals–furniture case) should be learned first, leading to global divisions before finer ones.[3] However, this order of acquisition occurs with the perceptual categorization of any data set, no matter how broad or narrow the elements may be. In itself it does not tell us whether the

[3]For example, in their connectionist simulations of this learning (Quinn & Johnson, 1998), the majority of inputs involved facial features, all of which have some positive value for animals but are zero for furniture.

features differentiating mammals, fish, and birds are easier to learn than those differentiating cats and dogs or poodles and terriers. In addition, with the exception of the unpublished study from our laboratory, we have no information about perceptual categorization of the larger animal domain. It may be that the class of animals as a whole is simply too varied in physical appearance to be categorizable by appearance alone (in addition to mammals, birds, and fish, think of worms). In any case, it is problematic whether a given picture-looking task results in domain-level categorization, whereas by 3 months infants are clearly able to form perceptual categories at the basic level in both the animal and furniture domains. Although Madole and Oakes (1999) recently suggested that conceptual processes might be at work in this performance, it seems unlikely (at least in our culture) that 3-month-olds are differentiating pictures of horses and zebras on a conceptual basis.

Interestingly, when one moves away from this kind of picture-looking task, different categorization data are obtained in the first year of life. In Mandler and McDonough (1993), we studied 7- to 11-month-olds using an object examination task (Oakes, Madole, & Cohen, 1991; Ruff, 1986). It uses a technique like that of Eimas and Quinn (1994), except that infants are given actual objects to handle one at a time, rather than shown pictures. In principle, increased examination of the object from the new category can be accounted for by perceptual similarity alone, at least for four-legged mammals and mammal subcategories, as found by Behl-Chadha (1996) and by Eimas and Quinn (1994) with 3- and 6-month-olds. However, our data from this task look more similar to the sequential touching data of our older participants than to the data of these investigators. Specifically, in the animal domain our 7- to 11-month-old infants categorized more consistently at the superordinate level (which if undifferentiated is more aptly termed the global level or domain level) than at lower levels. Infants in this age range not only differentiated animals from vehicles, but from 9 months of age also differentiated birds from airplanes, even though the exemplars all had outstretched wings and were very similar in shape. At the same time, 7- to 11-month-old infants failed the subcategorization tasks in the animal domain that 3- to 6-month-olds solve in the picture-looking tasks, in that they did not differentiate dogs from either rabbits or fish.[4] On the other hand, we did find subcategorization in the vehicle domain. (Southern California infants spend a good deal of time in cars, from which they observe a great variety of other vehicles. An earlier conceptual appreciation of different kinds of vehicles than of animals may be a subcultural difference, but this issue has not yet been studied.)

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[4]We have recently found one example of life-form categorization in the animal domain, namely, differentiation of dogs from birds (Mandler & McDonough, 1998a). Given Behl-Chadha's (1996) results with 3-month-olds showing this same differentiation, it may be that it can be done at either age by perceptual categorization of shape alone.

More recently we have used the same task to compare 7- to 11-month-olds' categorization of animals and vehicles versus furniture and plants (Mandler & McDonough, 1998a). These comparisons are necessary to eliminate the possibility that infants are only making an animate–inanimate distinction (or a distinction between natural kinds and artifacts) when they respond to a contrast of animals and vehicles. We found that by 9 months infants categorize furniture as distinct from both animals and vehicles, and at 11 months they make the distinction between both these domains and plants (we did not test plants before 11 months). However, when we tested the furniture subcategories of tables, chairs, and beds, from 7 to 11 months no categorization was found. Again, these findings contrast with the work of Behl-Chadha (1996), in showing categorization at a global, domain level accompanied by the absence of subcategorization.

The exact reasons for the differences in data from the picture-looking and object handling tasks are not yet known. I discuss here some possible reasons, although as far as the central thesis of this article is concerned the explanation is not crucial. What is crucial is that global categories of objects with exemplars that vary greatly in their appearance can be found at least by 7 months of age. It is important to determine the basis on which these are formed; it may or may not be relevant that all the studies showing domain-level categorization have used objects rather than pictures (see also Golinkoff & Halperin, 1983; Ross, 1980). There could be several factors accounting for the different data that have been found with the different stimulus materials. First, the photographs used in the picture studies provide more finely grained perceptual detail than those found in little models, even though the ones we use are not toys but realistic replicas. Second, objects elicit intense interest and active exploration from infants, which contrasts with the more passive looking found in picture studies. Longer looking at a perceptually novel item does not require conceptualization, as it can be the result of habituation to an automatically formed perceptual prototype. Conceptualization is almost certainly required for the sequential touching task, in which the infant must choose those objects with which to interact. The degree to which conceptualization is required for object examination seems less certain. However, the third point may be relevant: Object examination studies measure only those periods during which infants actively examine the stimuli, rather than total looking time, which is the measure used in the picture studies.[5] In general, examination constitutes only a portion of total looking time (Richards & Casey, 1992). It might be significant that object examination studies measure just those periods of intent examination that I have called *perceptual analysis* (Mandler, 1988, 1992); that is, periods of analytic observation in which conceptualization is taking place. Thus, even the simple object examination test may call on conceptual activity. Fourth, the

[5]We follow Ruff's (1986) procedures for measuring examining, which excludes mouthing, banging, and passive looking.

fact that infants interact with the objects may emphasize their conceptual, event-related aspects more than happens when they stare at pictures. These various suggestions converge on the idea that in very young infants conceptual activity may not be aroused by the picture familiarization and habituation test. The older the infant, of course, the less likely this would be true; at some point the different tasks should give the same results.

Of course, at any age and on any task perceptual appearance may be used to categorize objects, especially if perceptual similarity is emphasized and meaning is deemphasized. For example, Waxman and Markow (1995), using the same object examination test we used in Mandler and McDonough (1993), found that 12-month-old infants categorized cows as different from dinosaurs but were not responsive to the differences between animals and vehicles. However, they gave only half the number of familiarization trials we used. Because other investigators have confirmed our finding of global categorization of animals on the object examination task before 12 months of age (Oakes, Coppage, & Dingel, 1997) it seems likely that the different performance of the infants in the Waxman and Markow study was due to this change in technique. Providing only a few familiarization trials may be sufficient to allow perceptual categorization of perceptually similar items such as cows but insufficient for the more difficult task of noticing that the highly varied items being presented are all members of a superordinate category.

Regardless of the reasons for the differences that have been found between object handling and picture-looking experiments, we still need to understand the basis on which infants learn to categorize domains such as animals, plants, vehicles, and furniture. A straightforward hypothesis would be that even global domains have enough perceptual commonalities to allow some kind of perceptual prototyping. What might such commonalities be? Shape is almost certainly ruled out because individual members vary too greatly in this regard. Perhaps texture is the common feature that infants use. Although we minimize textural differences in our little models, real animals have fractal textures and most have softer contours than manufactured objects. To the extent that the models are seen as representing real-world objects, texture could be one within-category commonality. It has also been suggested that curvilinearity versus rectilinearity is a potential discriminator between animals and vehicles (Van de Walle, Spelke, & Carey, 1997). However, both these accounts have difficulty in accounting for infants' ability to differentiate models of furniture from vehicles and perhaps their ease in discriminating models of animals from plants as well.

These proposals that have been made for differentiating global domains on the basis of the physical appearance of their exemplars or the way they move, without regard to other possible commonalities, raise a number of questions. What are the rules governing reliance on individual features such as legs, overall shape, or other factors such as curvilinearity, to categorize at the superordinate level? When will features be used and when will they be ignored? Given that shape is used so easily by 3- and 6-month-olds, why do 7-month-olds often ignore it in our object manipulation tasks? Is there some criterion that determines when they begin to rely on curvilinearity or texture instead? Might they do so only when shape is too variable to be useful? But then how do we account for infants discriminating our models of birds and airplanes? Granted that the perceptual system should be flexible and sensitive to a variety of cues, these need to be specified, not called on in ad hoc fashion. It seems that a variety of perceptual biases will be needed to account for both basic-level and domain-level categorization, such that infants prefer features on some occasions, shape on others, texture on still others, or that they weight between-class differences more heavily than within-class similarities on some tasks and do the opposite on others. Even if these various factors can be ordered in a reasonable way, we still need to account for why curvilinear or textural commonalities that are called on to explain domain-level categorizing should constrain the inductive inferences that, as we will see, infants make. For example, why would infants assume that all curvilinear, but not rectilinear things drink? One might say that such assumptions are based on correlating attributes (e.g., curvilinearity and legs go with drinking, whereas curvilinearity and machine texture do not), but without any principle to organize the many possible correlations among attributes, such an approach risks becoming an ad hoc list.

We can see that an approach that relies only on perceptual appearance could rapidly become unparsimonious. It appears that the sum of the existing data will be easier to explain if more than one process is at work. To illustrate, we have recently tried to find some differentiation of the mammal category on the object examination test. Reasoning that infants in our culture would have the most experience with dogs and cats, we studied this contrast with 7-, 9-, and 11-month-olds. We found a straightforward progression from no categorization at 7 months to the beginnings of categorization at 9 months to successful categorization at 11 months (Mandler & McDonough, 1998a). These data can be contrasted with Quinn et al. (1993), in which on the picture-looking task infants categorized dogs and cats at 3 months. This discrepancy is not due to insensitivity of the object examination test because infants discriminate furniture from vehicles on it, whereas they do not do so clearly on the picture task (Behl-Chadha, 1996).

The differences in data the different tasks have produced in infancy are reminiscent of examples of nonmonotonic trends in development. Typically such trends are explained in terms of multiple processes at work. In the early stages of the development of some skill, such as reaching for objects or learning to balance blocks, children make use of procedural knowledge. As development proceeds, voluntary, higher order cognitive processes begin to take precedence, often resulting in a temporary setback in correct responding as children begin to conceptualize the phenomenon in question (Karmiloff-Smith, 1992; von Hofsten, 1984). Something similar may happen in categorization. Infants can make use of low-level perceptual schematizing skills from an early age and have no trouble applying these skills when looking at different animal or furniture shapes. Indeed, by 3 months of age infants can develop perceptual categories of such complex patterns as horses and zebras in as few as a dozen presentations. However, at some point infants begin to conceptualize what they are looking at. If the first conceptualizations are crude, when they begin to guide behavior in categorization tasks the resulting performance might appear as a loss in skill. The ability to conceptualize may take place subsequently to the first perceptual categorizations or roughly at the same time. The object examination data suggest that the conceptualizing process is active by 7 months, but that is a default assignment; there are signs that perceptual analysis begins earlier (e.g., Werner & Kaplan, 1963). I would not be surprised if conceptual processing begins near birth, but this issue awaits empirical verification from a methodology yet to be invented.

If physical appearance is insufficient to account for categorization of objects at the superordinate level, it is fair to ask why one must assume that a different skill (i.e., conceptualization) is required, rather than some other perceptual factor. For example, why not just call on the different ways that animals and vehicles move as the basis on which the categorization takes place? Movement is as much a perceptual factor as shape or texture. This suggestion is not unreasonable, and I have already indicated that movement is the initial basis for conceptualizing the roles objects play in events. The question is whether one should stop at the perceptual level in one's explanation of what infants are doing when they encode movement. There are several reasons why I believe we should not. It is a search for the foundations of meaning we are ultimately after, and there are already data indicating that from an early age infants interpret activities in terms of goals, not just as movement per se. For example, by 4 months infants have learned something about what hands do to objects (Leslie, 1982). Woodward (1995) showed that 5-month-olds attend to the goal of a reach more than to its spatiotemporal properties. In addition, as discussed later, by 9 months infants are organizing their conceptual inferences about animals, vehicles, and other domains around the goal-directed activities in which the objects are involved. A purely perceptual account of domain-level categorization in terms of differences in motion misses a crucial aspect of infants' attention to motion: They are not just perceiving it, they are interpreting it. Before describing the work on inductive inference, I briefly discuss how such an interpretive process might begin.

ONE WAY TO DERIVE CONCEPTS FROM PERCEPTS

Whenever they begin, it seems safe to assume that early conceptualizations are relatively crude in comparison with the perceptual categorization that is taking place. The ability to discriminate between photos of dogs and cats or horses and zebras after a few exposures suggests a sophisticated schematizing ability that makes use of fine perceptual details. Early concepts are almost certain to be much less detailed. It does not require any very sophisticated conceptualization to differentiate animals from other things. For example, one could characterize animals as things that move themselves and interact with other objects from a distance. The question is how infants arrive at even a simple concept such as this.

Traditionally there has been considerable doubt that infants have any conceptual categories at all (Piaget, 1952). Indeed, one of the classic developmental dilemmas has been how to get from a nonconceptual organism that categorizes the world on the basis of what things look like to an organism that responds on the basis of conceptually based processes. Piaget's solution was a stage theory in which a transition between one form of representation and the other was posited to occur around 1½ years of age. Piaget accepted that babies could form perceptual categories, which are typical kinds of sensorimotor representation. However, he was unable to provide a satisfactory account of how concepts are created out of this sensorimotor (procedural) base (see Mandler, 1998a). He said only that perceptual schemas gradually become freed from their sensorimotor limitations and are turned into images. Images allow sensorimotor infants late in the sensorimotor period to re-present absent objects to themselves and so to begin to think. How it is that forming an image of something conceptualizes it, however, or how an image represents abstract or functional properties is unclear (nor is there any evidence as to when imagery first develops).

In the classic empiricist account, on the other hand, infants are also said to form perceptual categories, but instead of there being a qualitative shift that turns them into concepts, they gradually turn into concepts by having information become associated with them. This is an enrichment position, in which perceptual categories accumulate more and more associations until they eventually begin to take on the characteristics of concepts (e.g., Eimas, 1994). For example, the infant learns the perceptual category of dog, say, and then begins to learn facts about dogs, such as that they bark, chew on bones, and have babies. What is not clear in this account is how these facts are represented. Are *chews on bones* or *has babies* themselves perceptual attributes? It is also not clear which attributes form the core concept of what a dog is. Presumably there can be no notion of dog as animal at this stage because animal is a superordinate concept that is said to require a long process of generalization across different animals and perhaps requires language as well (Quinn & Eimas, 1997). As we will see, however, the claim that a concept of dog can be formed without reference to the concept of animal makes it difficult to explain why infants use the domain-level concept of animal to control their associative generalizations about dogs before language begins.

The problem to be solved is how to reconcile concept formation with the constraint that infants learn about the world via the senses. I assume there are no innate concepts of dogs or motorcycles; concepts such as these must be constructed from observation of the world. However, it is not clear how they can be constructed just by adding associative links between one sight and another because that would only lead to a more interconnected set of perceptual categories and not to a conceptual form of representation. We need to understand how conceptual life begins, and it does not seem possible to get to thinking simply by more perceiving. I have proposed an alternative way of deriving concepts from perceptual data (Mandler, 1992). There are obviously a number of ways such an outcome could be achieved, but whatever mechanism is devised it needs to have several characteristics. One important requirement is that its output be potentially accessible, so that planning, problem solving, inference, and recall of the past can be carried out. This means that the conceptual function must be in place at least by 9 months because these functions are operative by this age (McDonough & Mandler, 1998; Meltzoff, 1988; Willatts, 1990). Equally important developmentally, the mechanism needs to produce an output that is appropriate for mapping into language.

With these requirements in mind, I proposed a mechanism of perceptual analysis as a way to create concepts (Mandler, 1988, 1992). I give a brief sketch here of how such a mechanism might work to illustrate one possible way of deriving conceptual representation from perceptual data. *Perceptual analysis* is defined as a process in which perceptual input is attentively analyzed and recoded into a new format. The name I gave to a process resulting in conceptualization is perhaps not ideal because it includes the term *perceptual,* but I chose it because the process works by analysis of perceptual data. It is the analysis that is crucial; that is a central process that differs from the usual perceptual processing, which occurs automatically and is typically not under the attentive control of the perceiver. More is needed than just attention, however. I have likened the process to the kind of work that adults do when they need to be able to remember someone they are meeting for the first time, so they analyze the person’s face in conceptual terms such as “thin mouth, hair swept back, big ears,” and so forth. Of course, adults have a conceptual system available in which to couch the results of such an analysis, whereas infants have to build that system in the first place. In both cases, however, selective attention is used to facilitate analysis and redescription of visual information into a simpler and explicitly realized form. In both cases it is this process that enables one to describe, recall, or think about something new, not just recognize it. Karmiloff-Smith (1992) described a similar process with her notion of *representational redescription*, which enables procedural information to be brought to awareness. I conceive of perceptual analysis as online, however, as in the examples described by Piaget (1951) of his infants’ attempts to imitate his blinking his eyes. Before they got the action right, they evinced an analogical understanding of what he was doing by opening and closing their hands or mouths while he was blinking his eyes. This understanding was more abstract than the specific gesture he was performing but seems clearly conceptual in nature and although gesturally realized must have been mentally represented in some way. I have suggested that the redescriptions that result from this kind of perceptual analysis are in the form of image schemas (Mandler, 1992).

Image schemas are simplified redescriptions of various relations that are involved when objects take part in events. In spite of their name they are not visual representations. Rather, they are abstract spatial representations of the paths that objects take; their onsets and endpoints; as well as various containment, contact, support, and contingent relations that obtain among objects. They have been described by cognitive linguists as the basis on which understanding of language takes place (Johnson, 1987; Lakoff, 1987). These researchers use image schemas to represent the underlying meaning of relational terms and the grammatical structuring of events (Langacker, 1987; Talmy, 1988) as well as analogical thought (Fauconnier, 1994). In so doing they have described a rich form of representation that is well suited for preverbal concept formation and appropriate as a conceptual base onto which language can be mapped (Mandler, 1994, 1996).

Most of the image schemas that have been analyzed have a kinetic or dynamic character, representing movement and, in some accounts, forces acting in space (Johnson, 1987; Talmy, 1988). Most of them seem easily derivable by an abstractive process that works on perceptual information and perhaps bodily kinesthesis. For example, one of the simplest image schemas is that of a path, representing any object moving on any trajectory through space, without regard to the perceptual details either of the trajectory or the object itself. Variations on the path image schema that could be formulated early in infancy are paths representing animate motion, inanimate motion, self-motion (i.e., motion that begins without anything else contacting the object), motion begun when another object contacts the first, and linked paths representing contingencies between one moving object and another. These image schemas can be elaborated recursively into more complex forms, such as source–path–endpoint, forming an initial concept of goal. Slobin (1985) suggested that notions such as these are combined into what he called a prototypical manipulative scene, in which (using my terminology) a self-mover causes an object to move. He suggested that this sort of preverbal understanding is what enables the morphemes associated with grammatical relations such as transitive verb phrases to be acquired so easily across the languages of the world. In addition to their role in language acquisition, I have claimed that they are the first kinds of meanings that infants form (Mandler, 1992). These elemental meanings are combined to form concepts, not only of kinds but also of relations such as containment.

Of course, something must determine the kinds of perceptual input that get selected for perceptual analysis and undergo redescription into image schematic meanings. Understanding the origins of the first meanings is a difficult and speculative topic, but at the very least we can say that infants are especially attracted by moving objects (Kellman, 1993). This interest may be built in, but it may also be determined at least in part by the initial limitations of infants' perceptual systems, such as poor acuity in the first few weeks of life (Banks & Salapatek, 1983). Indeed, given newborns' relatively slow processing they may not at first retain much information out of many events except crude descriptions of the paths that objects take. Although we do not know when perceptual analysis begins, characteristics of these paths such as biological motion or contingent motion are the sorts of information I have suggested infants analyze to form their first conceptions of the different kinds of things to be found in the world; that is, it is the beginning of what I have called here the setting up of kinds. Thus, perceptual analysis selects and describes at a relatively abstract level the paths that characterize events. Notice that these paths are not the same as the perceptual categorization of motion. For one thing, the information is couched in a more abstract form. For another, continuous perceptual parameters have been redescribed into small, discrete packages. This packaging is essential both for thought and for language because it creates a discrete form of representation with elements that can be combined in a productive manner. This packaging also makes information potentially accessible.

I illustrate how this process of concept formation might work with a brief account of the possible origin of the concept of animal. Infants perceptually differentiate the motion of people from similar but biologically incorrect motion as young as a few months of age (Bertenthal, 1993). It is not yet known whether they can make the even more abstract categorization of animate and inanimate motion in general. I have assumed that they can and that perceptual analysis can be applied to this kind of information. The categorization itself is a purely perceptual process, responsive to the many parameters that differentially characterize biological and nonbiological motion. What perceptual analysis does, in addition, is to abstract a few spatial aspects of the paths these different kinds of objects take, including the way they begin and end, and strip away most of the perceptual details. It is in this sense that they are not the usual perceptual processes but redescriptions of those processes. The various parameters of animate motion are being reduced to highly simplified descriptions such as "irregular motion," "self-motion," or "interacts with other objects from a distance" (see Molina, Spelke, & King, 1996; and Poulin-Dubois, Lepage, & Ferland, 1996, for evidence of infants' sensitivity to these variables). In this way image schemas representing biological motion, self-motion, and contingent motion would be independent of the actual appearance of the movement of any particular object; that is, whether it is realized by legs, fins, or wings. Nevertheless, a combination of several such meanings would be sufficient to establish a primitive concept of animal in the sense that they create a nonperceptual description (or very abstract perceptual description) of the sort of thing an animal is.[6]

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[6]It is debatable whether these simple spatial descriptions require some kind of innate vocabulary. In my opinion most of the work is being done by simplification of incoming perceptual information into schematic form, and the resulting image schemas themselves create the initial vocabulary.

It may be noted that this emphasis on events as crucial to the formulation of notions about kinds is similar to a view long espoused by Nelson (e.g., 1974a). She placed more emphasis on function than does the account here, but I am talking about processes that begin earlier in infancy than she proposed. Analysis of motion may underlie the later development of understanding of function (Mandler, 1998b). In any case Nelson (1973) made the important point that the core of understanding what a ball is, for example, has more to do with the fact that it rolls than what it looks like. It may also be noted that I have proposed that early meanings are represented in analogical form as image schemas, but of course they could be represented in other formats instead, such as Barsalou's (1993) perceptual symbols or Fodor's (1975) propositional language of thought. The format is not crucial to the argument that I am making, namely, that it is these redescriptions that give objects meaning and make an infant construe them as particular kinds of things. The crucial part of the argument is that conceptualization does not accrue automatically, serendipitously, as a function of a history of perceiving; it requires attentive analysis. The exact nature of the analysis may be quite different from the theory I have proposed, but it seems plain that developmental psychology needs some theory of this general type to account for the origins of thought.

To summarize, I have suggested that the first conceptual categories are formed in infancy when infants begin to analyze what they are looking at. Although in principle nothing prevents them from using perceptual analysis to conceptualize object features, shapes, colors, and other details of perceptual appearance (and they may at times do so), it seems plausible that this process would usually be directed toward objects as wholes and specifically toward what those objects are doing. I have suggested further that analysis of the interacting paths that objects take leads (via image schema formation or some similar redescriptive process) to concepts of different kinds of things—animate things, inanimate things, agents, and patients. There must be more to this story, but it is a way of getting a conceptual system off the ground.

Regardless of its ultimate correctness, the view I have espoused can account for the ease with which infants in our experiments differentiate animals from vehicles. They do not need to rely on physical features in common or overall perceptual similarity or dissimilarity to tell these things apart. They only need to use a few characteristics to differentiate these domains. Dogs, fish, and rabbits all equally fit the notion of animals as things that move by themselves. If the initial concept of animal is such a simple one, there may be no basis to make a conceptual distinction between one of these subcategories and another, so in many tasks infants treat all animals as the same sort of thing. This should not really be a surprising result because infants have had relatively little opportunity to learn conceptual differences between one animal and another. It may be more surprising that infants take a representational stance so early. Our little models, although realistic, are not only not moving, but they carry considerably less information than do real objects engaging in events. I show in the next set of experiments on inductive inference, however, that infants do treat the models as representations of the world and are using a conceptual system to guide their inferences.

CONCEPTUAL CATEGORIES ARE USED FOR THE FIRST INDUCTIVE INFERENCES

All categorization results in something less particular than a given instance, whether it be perceptually or conceptually realized. The main difference for purposes of inductive inference seems to be the notion of kind. Since the pioneering work of Carey (1985) and Gelman and her colleagues (e.g., Gelman & Markman, 1986) we have known that preschool children make inductions on the basis of conceptual kind rather than on the basis of physical similarity. These studies taught children a fact about an object, and then they were asked to decide the categorical range over which the taught property is valid. At least from 2½ years of age, children use conceptual class membership to constrain their inductions, and they do so in preference to perceptual similarity between training and test exemplars (Gelman & Coley, 1990).

Until recently, however, there was no information on inductive inferences in younger children, particularly in the infancy period. Does inductive generalization originally begin on the basis of perceptual salience or do even infants use more principled bases for their generalizations? McDonough and I have been investigating how infants go about making generalizations about the characteristic properties of objects. Some of the questions we have asked are the following: When infants observe that a dog eats or sleeps, how far do they generalize such behavior—only to other dogs, to all animals, or to all objects? That is, do category boundaries constrain their inductions, and if so, how broad are these categories? How much of a role does physical similarity play? For example, will infants generalize a bird eating to an airplane eating? Or will infants constrain their inductions to the animal class but be more likely to generalize eating from a dog to a similar-looking mammal than from a dog to a fish?

The traditional empiricist doctrine of induction, exemplified in modern times by Quine (1977), is that the first inferences are based not on conceptual kinds but instead on raw perceptual similarity. Quine posited that infants and young children use an innate animal sense of similarity to make their first generalizations because they do not yet have any concepts at their disposal. Keil (1991) dubbed this the doctrine of original sim: Before children develop theories about the world, they can only be influenced by similarity of appearance. The more two things look like each other, the more likely it is the infant will generalize the properties of one to the other. In this kind of view, upon seeing the family dog eat, the infant comes to expect that other dogs eat as well. The generalization happens because a category of dogs can be formed on the basis of the innate sense of similarity. With experience, the infant observes cats eat, birds eat, and various other animals eat, and eventually (perhaps with the help of language) makes the more difficult inference that all animals—even though they do not look alike—eat.

There are a number of difficulties with this view of the foundations of inductive inference. First, it implies that a global category of animal already exists. Otherwise the infant might infer that all objects eat: Without an animal category boundary there is no stop rule. To be sure, the infant has negative evidence, never having seen cars or chairs eat, but in all likelihood the infant has never seen turtles or elephants eat either. At best there might be a perceptual similarity gradient around the objects initially observed to eat, but this would surely map very imperfectly onto such a diverse domain as animals. Second, as I have noted throughout this article, this approach does not tell us how anything conceptual ever emerges. Indeed, as Keil (1991) pointed out, no one espousing the traditional view has shown how generalization on the basis of physical appearance gets replaced by more theory-based generalization. As we will see in the studies of induction described next, we cannot leave the infant in a state in which he or she has perceptual categories of different levels of generality (but no concepts) and still be able to explain why one level of categorization is used for induction and not the other.

Given that infants' early conceptual categories seem to be little influenced by surface perceptual similarity, McDonough and I predicted that the first inductions would not be so determined either. The technique we use to study this issue is to model actions with little models of animals and vehicles and see if infants imitate the actions afterward on different exemplars from these domains. We chose this technique because infants are more likely to imitate actions that make sense to them than actions they find odd (Killen & Uzgiris, 1981; O'Connell & Gerard, 1985). In the first set of experiments (Mandler & McDonough, 1996a), we studied 14-month-olds and modeled actions appropriate either to the animal domain or to the vehicle domain. We modeled giving a dog a drink from a cup or sleeping in a bed, and we modeled turning a key against a car door or a car giving a child a ride. Following each modeling, a generalization test was given. The modeled item was put away and a different animal and vehicle were brought out and put on either side of the prop that had been used (e.g., the cup). We measured which object, if either, the infants used to imitate what they had seen modeled.

We assessed the role of perceptual similarity by using animals and vehicles that we judged to be either physically similar or dissimilar to the modeled objects. Thus, when we used a dog for modeling, half the infants received an animal similar to the dog for the generalization test (a cat or a rabbit) paired with a vehicle. The other half of the infants received an animal dissimilar to the dog (a bird or a fish) paired with a vehicle. When a car was used for modeling, half of the infants received a similar vehicle (a truck or a bus) paired with an animal for their generalization test. The other half received a dissimilar vehicle (a motorcycle or an airplane) paired with an animal. In this way we could test the breadth of the generalizations the infants made. That is, we tested whether infants generalize from a dog to a cat or a rabbit more frequently than to a bird, fish, or vehicle; and whether they generalize more from a car to a truck or bus than to a motorcycle, airplane, or animal.

The results were straightforward. The infants strongly preferred to perform the actions on the exemplars from the appropriate domain (67%) and rarely crossed the appropriate domain boundary (11%). As long as the test exemplar was from the same category, it did not matter whether it looked like the dog they had seen or not—they were just as likely to imitate giving a drink to a cat, rabbit, fish, or bird, and, after seeing a car being keyed, to key a truck, bus, motorcycle, or airplane. Thus, there was no effect of the physical similarity or dissimilarity of the exemplars within a domain on generalization. It is also of interest that the infants generalized keying to airplanes, given that the only vehicles they are likely to have seen keys used with are cars. Their domain-wide generalization suggests overgeneralization that in some instances, such as fish drinking, will later need correction.

We replicated this experiment using highly atypical exemplars (e.g., an armadillo and a forklift) so we could be sure the infants had not seen the particular exemplars before (Mandler & McDonough, 1996a). The same pattern of results was found (72% appropriate vs. 13% inappropriate). We then used a more difficult test. We modeled the actions on both the correct and incorrect exemplars. For example, we modeled turning a key against the car door but also modeled turning the key against the dog's side. This is a stringent test because our modeling of the actions on inappropriate exemplars essentially tells infants that in this game it is okay to do odd things. The results, however, were very similar to those obtained before; there was only a slightly greater tendency to use the inappropriate object that we had just modeled for them. So even when encouraged to imitate inappropriate properties, relatively few babies did so.

We have also extended the generalized imitation method to 9- and 11-month-olds (McDonough & Mandler, 1998). We had to use a somewhat simpler technique, but again the data mirrored the results of the first two experiments already described. Fewer of the 9-month-olds imitated than older infants, however. We cannot be sure, therefore, whether 9-month-olds are at the lower age limit for this kind of inductive generalization, or whether at this young age imitation of complex events is too difficult to provide a viable technique to examine any such generalizations that are taking place.

In more recent work we studied domain-neutral ("accidental") properties along with a set of the domain-specific properties studied earlier (Mandler & McDonough, 1998b). In addition to the properties of drinking and being keyed, we modeled going into a building and being washed. The patterns of generalization were quite different for domain-neutral and domain-specific properties: 14-

month-olds generalized across domain boundaries in the case of going into a building but did not generalize drinking and keying across domains. Both this and the previous result of refusing to imitate modeled behavior when it is inappropriate are important because they demonstrate that infants are not merely treating our little models as toys, but are treating them representationally. If they were considering the situation merely a game of "follow the experimenter," then they should behave the same way toward domain-specific and domain-neutral properties, but they do not. Instead they treat the objects and actions appropriately.

I stress the representational response of infants in the age range of 9 to 14 months because it is such convincing evidence of conceptual functioning. It is usually assumed that infants this age have not yet formed a representational capacity, using the term *representation* here not merely as conceptual knowledge but in the more traditional sense of using one object to stand for another. Because of Piaget's theory and also because of DeLoache's (1989) work showing the great difficulties 2-year-olds have in using scale models (and photographs) as representations of other objects, it is usually assumed that this is a late-developing capacity. However, we know that by around 18 months infants begin to use one object to stand for another in symbolic play (McCune-Nicolich, 1981). In addition, DeLoache showed that although 2-year-olds have trouble using a photograph to help them find an object hidden in a depicted room, they can nevertheless use the photograph to help them hide something in the room (DeLoache & Burns, 1994). Thus, the representational capacity is multiplex and appears to undergo considerable development; our imitation data indicate that its roots are present even in the first year.

We have recently completed a series of experiments investigating whether there are any generalizations that are restricted to the basic level. The first of these is reported in Mandler and McDonough (1998b). We investigated artifact properties such as that beds are used for sleeping and cups are used for drinking, and natural kind properties such as that dogs eat bones and flowers are to be smelled. We found that 14-month-olds overgeneralize these properties. For example, when we demonstrate giving a little model of a person a drink from a tea cup and then give the person to the infant along with a coffee mug and a frying pan, they are as likely to choose the frying pan as the mug to imitate drinking. It is as if they are conceptualizing these utensils as containers and have not yet narrowed them down to their common social uses. Similarly, they are as likely to put a little person to sleep in a bathtub as in a bed, to smell a tree as a flower, and to feed a bone to a bird as to a dog. Even at 20 months, infants are still making some of the same overgeneralizations. They have begun to narrow the artifact characteristics appropriately, but are still overgeneralizing the natural kind characteristics (presumably because of fewer interactions with animals and plants than with artifacts). We have since replicated these findings with other properties and shown that the overgeneralizations made do not extend beyond domain boundaries; for example, 14-month-olds use a toothbrush to groom hair but not a spoon, and they hammer with a wrench but not a cup (Mandler & McDonough, 1999). Needless to say, we do not conclude that young children cannot restrict inductions to subcategories in either natural kind or artifact domains. Indeed, we assume that one of the functions of the names that parents use with children is to teach them that there are smaller categories than the domain level that are important and that constrain some kinds of properties. Nevertheless, it appears that before the onset of language, the earliest inductive inferences tend to be remarkably broad.

Overall, these induction data are consistent with our previous categorization findings. Thus, our findings from the object examination task, the sequential touching task, and the generalized imitation task converge on the conclusion that infants initially form broad, relatively undifferentiated concepts of animals, vehicles, furniture, and plants (with some evidence that artifacts become differentiated earlier than animals and plants, including earlier correct assignment of basic-level properties; Mandler & McDonough, 1999). Furthermore, these tasks all indicate that these domain-level concepts are not organized around individual features or overall perceptual appearance, but rather around some (possibly quite primitive) notion of kind.

In addition, these data tell us something very important about the way infants form associations. They indicate that property association and generalization are controlled not by the common features of objects or by the perceptual appearance of the objects that infants have actually observed, but instead are organized by the concepts infants have formed. In the initial stages the boundaries of these concepts are very broad. The world has been divided into a few global domains of different kinds of things. The meaning of these broad classes, such as animals or vehicles, does not arise from commonality of physical features. Babies do learn at least some of these features, of course; indeed, they must learn them to identify an object as a member of a particular category. In terms of meaning, however, it appears that infants observe the events in which animals and vehicles take part and use their interpretation of the events to conceptualize what sort of thing an animal or a vehicle is.[7] Animals are things that move themselves and act on other things; vehicles are things that give animals rides. The most important aspect of this meaning creation is that it is the meaning of the class as a whole that determines what gets associated with what, not just the individual objects or features of objects actually experienced. So, for example, drinking is associated with self-movers and with

[7]It may be noted that this is not the same as slot filling (Lucariello & Nelson, 1985). According to Lucariello and Nelson, the common function of daily events enables infants to form small categories such as things to eat at breakfast, things to eat at lunch, and so forth. These slot-filler categories then require a higher level of abstraction to form the superordinate category of food. My thesis is that the initial conceptual basis is more general than function and characterizes superordinate generalizations from the start.

containers, not just with the dogs one has seen drink or the cups one has drunk from. Note that this view does not claim that no associations between dogs and drinking or cups and drinking are formed—only that initially the associations are broader than that.

Thus, even though infants must use various physical features to tell animals such as dogs and cats apart, they do not rely on them when they are construing the meaning of an event or even when generalizing from it. When we model an event with a dog and give infants a choice between another dog and a cat or another dog and a rabbit to use for their imitations, they are as apt to choose the cat or the rabbit as the dog (Mandler & McDonough, 1998b).[8] They do not give a drink to a Flying Tiger airplane in spite of its prominent mouth. They use a key on forklifts and airplanes, associations that, of course, they have never observed. Infants presumably have not seen people sleeping in bathtubs or drinking from frying pans either, yet they generalize broadly to these pieces of furniture and containers. All of these phenomena provide evidence that associations are not controlled by individual features or objects but instead by object kind.

I assume that from an early age infants pick out features such as eyes, mouths, wheels, and windows. Some such features are necessary to recognize a new little exemplar as a member of a class. However, eyes and mouths have become associated with animate things moving and wheels and windows have become associated with inanimate things moving, and so these features can be used to identify these objects even when they are not engaging in their customary activities. In the typical real-world case, infants see a familiar object with various features engaging in animate activities. In our imitation task, the infants see only the features and must infer the relevant concepts. (Although our modeling provides relevant information, it does so only for the modeled objects, not the generalization objects.)

Why should we not say, then, as did Haith and Benson (1998), that because physical features are required to recognize an exemplar as a member of a category, it is those features that define the category? These investigators suggested that infants form a category first on the basis of physical features, and then they infer other characteristics as a result of the categorization. Given the great difficulties adults have forming disjunctive categories (Bruner et al., 1956), it seems unlikely that infants could do so by aggregating over the highly varied features found in superordinate categories (e.g., legs or fins or wings, fur or feathers or scales, etc.). This has been the major argument for why superordinate categories should be late developing—they do not have common features (Rosch & Mervis, 1975; Smith & Medin, 1981). The hypothesis also does not fit well with infants' lack of attention to many physical features or with the need for attention to detail that such an ana-

[8]Once again, however, we find more selectivity in the vehicle domain. Infants are more likely to pick another car to imitate a car event than a truck or airplane (Mandler & McDonough, 1998b).

lytic attitude would require, as exemplified by the basic-level induction data just described (Mandler & McDonough, 1998b). If an infant categorizes a cup, for example, solely or even primarily on the basis of its physical features, why do these features not control the associations of drinking with it? If an infant categorizes a car on the basis of four wheels, doors, and windows, why do these features not control the associations with keying? I agree with the importance of commonalities, but at the level of superordinate categories these are difficult to find insofar as physical features are concerned. Instead, the commonalities seem to reside in how exemplars behave within the context of events. The commonalities I have talked about, such as animate or inanimate motion, self-motion or caused motion, interactions with objects from a distance or being acted on by others, do characterize superordinate domains and should make it relatively easy to do global categorization. Once the global category has been formed, then different kinds of limbs or facial features can be associated with it.

I stress, however, that this point of view does not deny that perceptual similarity can influence the likelihood of making a generalization, particularly when making inferences within conceptual domains (e.g., Gelman & O'Reilley, 1988). Even adults often have little information to differentiate one animal species from another except physical appearance. To the extent that is so, they must rely on perceptual similarity and dissimilarity to regulate their inferences. However, they use differences in perceptual appearance to distinguish one kind from another, which is not the same as asserting that associations or generalizations are made on the basis of these differences.

CONCLUSIONS

I have argued for the necessity of distinguishing between conceptual and perceptual categories. Some such distinction is necessary because both kinds of categorization occur in young infants. Infants certainly do make use of similarity of appearance in forming perceptual categories and do so with ease and from an early age. However, infants also form conceptual categories at least by 7 months of age and do so in a way that largely ignores surface similarity. I would characterize the bases of the earliest concepts as theory-like, in that a small set of abstract distinctions is being used to define animals, vehicles, plants, and furniture as different kinds. I call these distinctions *defining* because they are necessary and sufficient for the simple inferences that infants make: What something looks like does not matter as much as whether it has these characteristics. These characteristics are more abstract than perceptual features. For example, even though motion can be considered a perceptual feature, what that motion actually looks like is not included in the notion of self-motion or the role of agent. These notions are themselves no longer perceptual (unless one wants to say that all mental processes are perceptual). Interestingly, the characteristics that seem to act like necessary and sufficient conditions for the infant may do so because the conceptual base is so meager. If the only way an infant conceptualizes an animal is as a self-mover, then if something cannot move by itself, how could it be an animal? This is undoubtedly something of an exaggeration, but it does suggest how concepts might be built up around a core that acts like a definition in spite of the more variable accretions of later experience that temper and qualify the initial formulation. The result would be the kind of radial categories built around core notions that typify adult cognition (Lakoff, 1987).

Even in this approach, perceptual information is fundamental. If I am correct that the earliest concept of animal is something like a self-mover that interacts with other objects from a distance, the underlying bases for these notions are information given by the perceptual system. In addition, infants must use perceptual appearance to identify an object as a member of a given conceptual class. There are to date almost no data on the physical features they use for this purpose. The work of Quinn and Eimas (1996) suggests that faces may be important for identifying animals; their data indicate that face information is more important than body shape in 3-month-olds' differentiation of pictures of dogs and cats. This finding may be due to the detailed face information in the pictures they use, or perhaps to an innate bias to attend to faces (Johnson & Morton, 1991). However, in our work with older infants, face information does not seem to be crucial to the assignment of conceptual class. Our birds all have beaks, not mouths, and some have no other facial markings but are categorized as animals. Some of our planes have distinctive Flying Tiger facial markings but are categorized as vehicles. We have virtually no information about the features used to identify exemplars in other domains.

In any case, infants are not relying on individual features to constrain their inductions. Keys are associated with car doors in babies' experience, yet they generalize this association to motorcycles, forklifts, and airplanes. Cups and glasses are associated with drinking, but the association is generalized to frying pans. It appears that it is not just doors or cars that are being associated with keys, but vehicles, and it is not just cups or mugs being associated with drinking, but containers. Thus, the data I have described suggest that physical features and the similarity relations they produce are used for identification purposes rather than to constrain the associative learning that builds the knowledge base.

It is for reasons such as these that I have argued for the necessity of differentiating perceptual and conceptual similarity in concept formation. At least in the early stages of development when the basis of the human conceptual system is being laid down, there is evidence that perceptual similarity is not much used in its formation. It is being used for perceptual categorization, but that is different from conceptual categorization, which depends on other kinds of information than what objects look like. There are several ways in which this difference manifests itself in the infancy period and, at least to some extent, throughout life.

First, perceptual categories work on different kinds of information than conceptual categories. This first difference may be considered a matter of definition. There is an important distinction to be made between people's summary representations of what things look like and their summary representations of what things are. Perceptual categorization computes perceptual similarity. At least early in infancy it does so independently of knowledge about function or kind; indeed, it can occur even in the complete absence of meaningfulness. We could even say that it is not categorization at all but perceptual schema formation, reserving the term *categorization* for conceptual categories. If we did, some of the many arguments in this area might fall away. Conceptual categories (in the realm of objects) compute conceptual similarity, which has to do with class membership or kinds. The concept of a kind may include a perceptual description, but its initial core is the assignment of the object to a domain, which itself is characterized by a few abstract characteristics, typically having to do with event or role information.

Second, perceptual categories contain more detailed information (at least in infancy) than do conceptual categories. A perceptual procedure that can tell dogs from cats in a few brief trials is probably operating on a great deal of detailed perceptual information (even if confined to the face region) to extract a summary representation. Many early concepts, on the other hand, appear to be global, relatively crude, and lacking in detail, as exemplified by infants' ability to conceptually differentiate animals from vehicles but not most animals from each other.

Third, much of the information in perceptual categories is inaccessible, whereas the contents of concepts are accessible for purposes of thought, problem solving, recall, and so on. There is virtually no direct information on accessibility in infancy, and so we may have to generalize from adults. There is ample evidence that for adults perceptual categories are impenetrable; as mentioned earlier, we have no access to the information that enables us to categorize a face as male or female. Whatever this information is, it cannot be considered part of our concept of a face. We use this information to identify male and female faces, but we do not "know" what it is and so cannot think about it. Given lack of accessibility to this kind of information in adulthood, it seems somewhat unlikely it would be accessible in infancy. As for the converse, that concepts are accessible to infants as well as to adults, the ability to imitate past events as infants can do at least from 9 months of age (Mandler & McDonough, 1996b; Meltzoff, 1988) requires not only conceptualization but also accessibility, as shown by the inability of amnesic adults to do such imitation (McDonough, Mandler, McKee, & Squire, 1995).

Fourth, there is a different course of acquisition for the two kinds of categories. There are still not many data on infants' acquisition of perceptual categories at different levels of generality, but we do know that even very young infants are proficient categorizers at what is usually called the basic level. For conceptual categories, on the other hand, even older infants are more proficient at making a few broad distinctions that separate one domain from another than they are at making the finer distinctions required to categorize at the basic level.

Last and most important, perceptual and conceptual categories serve different functions. Perceptual categorization is used for recognition and object identification. Conceptual categories, on the other hand, are used to control inductive generalization (and for other kinds of thought as well). Infants, just like adults, make their inductive generalizations on the basis of kind and not on the basis of perceptual similarity. Of course adults do make use of perceptual similarity in their inductions, but they use it to help determine kind and not as a basis for induction in its own right. No matter how much something may look like an animal, if we think (for whatever reason) it is not an animal, we will not ascribe animal properties to it. The same is true for children. Carey (1985) showed that even young children will not induce animal properties (such as having a spleen) to a toy monkey; Massey and Gelman (1988) made a similar point.[9] Our data show that infants, too, are constrained by their notions of kinds, as crude as these may be.

Our developmental exploration has shown that beginning early in infancy more than one kind of categorization occurs. Given their different functions, reliance on different kinds of information, different degrees of selectivity in the information that is used, probable differences in accessibility, and different developmental time courses, it would seem wise not to assume that categorization is categorization is categorization. At the very least we must distinguish between perceptual categorization, which automatically computes perceptual similarity, and conceptual categorization, which rests on determining meaning. I have speculated that meaning in turn rests on what objects do, not what they look like.

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[9]Note that in these studies children were asked whether the representation itself (picture or model) has the properties (e.g., whether a doll can actually walk, not whether it represents something that can walk).

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