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The Development of Object Categorization in Young Children: Hierarchical Inclusiveness, Age, Perceptual Attribute, and Group Versus Individual Analyses

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Multiple levels of category inclusiveness in 4 object domains (animals, vehicles, fruit, and furniture) were examined using a sequential touching procedure and assessed in both individual and group analyses in eighty 12-, 18-, 24-, and 30-month-olds. The roles of stimulus discriminability and child motor development, fatigue, and actions were also investigated. More inclusive levels of categorization systematically emerged before less inclusive levels, and a consistent advantage for categorizing high versus low perceptual contrasts was found. Group and individual analyses generally converged, but individual analyses added information about child categorization over group analyses. The development of object categorization in young children is discussed in light of efficiency of processing and similarity–differentiation theories.

Keywords: categorization, sequential touching, toddlers

Generally speaking, categories mediate interactions with the world (L. B. Smith, 1989) insofar as they structure and clarify perception and cognition (Bornstein, 1984; Harnad, 1987). The environment affords an infinite variety of stimulation and is incessantly changing. Moreover, human beings experience the world out of a constant biological flux. Both these major sources of variation must be reduced if perception and cognition are to proceed with organization, order, and coherence. Categorization contributes to rendering comprehensible this otherwise bewildering diversity, allowing us to generalize across experiences, because categorization relates each experienced entity to an extant representation (E. E. Smith & Medin, 1981). Categorization also facilitates the storage and retrieval of information, and it supplies a principle of organization by which new information can be banked efficiently in memory. In this way, categorization implies an elementary kind of inference and allows the categorizer to respond to novel entities as if they were familiar. Object categories refer to shared representations of like but discriminable objects. Object categorization conveys knowledge of other object properties as well as knowledge of properties of category members not yet encountered (Baldwin, Markman, & Melartin, 1993; Greco, Hayne, & Rovee-Collier, 1990; Mandler, 1998, 2000). In brief, categorizing is an essential cognitive and developmental achievement but also presents a formidable cognitive and developmental challenge.

Categories are especially valuable in infancy and early childhood, when many new objects, events, and people are encountered, because without the ability and proclivity to categorize, children would have to learn to respond anew to each novel entity they experience (Bornstein, 1984; Rakison & Oakes, 2003). In this sense, insights into how categorization initially develops are fundamental to understanding children's cognitions as well as other emerging related mental functions, such as memory and language (e.g., Mareschal, Powell, & Volein, 2003). In consequence, the need to understand more about the early development of categorization is patent, substantive, and compelling.

Object Categories and Their Hierarchical Inclusiveness

Two views on categorization complement one another. One emphasizes processing, and the other focuses on structure. In terms of processing, entities in the world can be categorized in different ways: The properties and entities that people encounter every day are not each bound into a single category but can be situated into different categories. Adults flexibly categorize the same entities in different ways in response to changing instructions, contexts, and task demands (Schyns & Rodet, 1997). So do young children. As children become familiar with the objects in a task, they can change their categorizations (Oakes, Plumert, Lansink, & Merryman, 1996); whether children form a category that includes or excludes certain exemplars depends on the distribution of exemplars they are exposed to (Bornstein, Kessen, & Weiskopf, 1976; French, Mermillod, Quinn, & Mareschal, 2001; Hund & Plumert,

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2005; Oakes & Ribar, 2005). Different properties of category entities (prototype exemplars or not, exemplars presented singly or in pairs) shape children's categorical responding (Bauer, Dow, & Hertzgaard, 1995; Mareschal & Tan, 2007; Oakes, Coppage, & Dingel, 1997; Younger & Furrer, 2003), and children can shift from categorizing a set of stimuli by means of one dimension to categorizing the same stimuli by means of a different dimension (Ellis & Oakes, 2006). Jones and Smith (1993) succinctly argued this dynamic process view of categorization, asserting that categories are "emergent products of multiple knowledge sources in specific task contexts" (p. 136). However, categorization is not totally, always, or only ad hoc.

The complementary approach to process in categorization is structure, and a central feature of category structure is hierarchical inclusiveness, the taxonomic organization of more encompassing categories subsuming less encompassing ones (Callanan & Markman, 1982; Collins & Quillian, 1969; Murphy, 2002). For a simple example, a collie is a type of dog, which is a type of animal. When people spontaneously categorize objects in a neutral setting, they typically categorize into hierarchically organized taxonomies that have nested categories connected by relations. Hierarchical networks allow for set inclusion (sometimes called the "IS-A relation") between category levels (Murphy, 2002). The taxonomic system for organizing species is a prime example, and it is important to note that it is found widely across human cultures (Atran, 1990; Berlin, Breedlove, & Raven, 1973, 1974). Category hierarchical inclusiveness represents fundamentally different levels of reality and not convenience (Berlin, 1992). Many entity domains around us are organized hierarchically with different levels of inclusiveness, normally on the basis of their instrumental and/or perceptual attributes.

At high levels of category inclusiveness (L_1), category members are grouped instrumentally and share some perceptual attributes; thus, within-category instrumental similarity tends to be high and perceptual similarity middle to high, whereas between-category instrumental and perceptual similarity tend to be low. For example, dogs, horses, rabbits, and fish are all subsumed under the more inclusive L_1 category of animal because animals share multiple properties, but different animals do not (necessarily) look alike; moreover, the animal domain differs from other inclusive L_1 category domains, such as vehicles, in instrumental and perceptual properties. At middle levels of inclusiveness (L_2), entities share instrumental and usually (although not always) perceptual properties; thus, within-category instrumental and perceptual similarity tend to be high, whereas between-category instrumental and perceptual similarity tend to be middle to low. For example, dogs of different species share multiple characteristics as well as a number of perceptual properties, and dogs are easily distinguished from fish, a different L_2 category in the same (L_1) domain of animals. At low levels of category inclusiveness (L_3), members of a category share both instrumental and perceptual similarity, which tend to be high; however, between-category instrumental and perceptual similarity (for categories nested within the same L_2) also tend to be high. For example, collies, shepherds, and retrievers represent L_3 categories of dogs; members in each category are discriminable from one another, yet they are also similar to one another.

In this study, we defined and tested three levels of inclusiveness in young children's categorization. Two interrelated comments about them are in order. First, the appellations of L_1, L_2, and L_3 are symbolic of three levels of hierarchical inclusiveness and are not intended to convey fixed or exhaustive relations within or across levels. For example, one could hypothesize an L_0, the level of "things" to which both animals and vehicles belong; $L_{0.5}$, living things versus nonliving things; $L_{1.5}$, mammalian vs. nonmammalian animals; or L_4, different categories of collie (e.g., scotch collies, border collies, rough collies). Second, this hierarchy is reminiscent of but not isomorphic with the taxonomy of "superordinate–basic–subordinate" categorization that has been so prominent in infant, child, and adult cognitive studies (e.g., Ellis & Oakes, 2006; Liu, Golinkoff, & Sak, 2001; Mervis & Rosch, 1981; Murphy, 2002; Rosch, 1978). It should be clear, however, that a term like superordinate, for example, is arbitrary rather than absolute. Is animal superordinate? If so, then what about things (L_0, above) and so forth? Furthermore, basic to an expert or a person in one culture may be subordinate to a novice or a person in another culture (Dougherty, 1978; Tanaka & Taylor, 1991). To discuss category inclusive relations in the confines of this article, we therefore use the more neutral and simply relative terminology L_1, L_2, and L_3.

The present developmental study proceeds from the structural perspective on categorization. Our main goals were (a) to chart the developmental trajectory of category inclusiveness, (b) to explore the role of perceptual attribute in category development, and (c) to compare group versus individual analyses of children's categorizing.

Development of the Categorization Inclusiveness Hierarchy

Given the vital necessity of categorizing and its process nature, it is not surprising that infants categorize a wide variety of properties and entities (Bornstein, 1984; Rakison & Oakes, 2003). However, extant studies vary in child age, stimuli, and method, constraining our understanding of the development of object category structure. To study development in this arena, what is required is to compare multiple levels of inclusiveness in the same domain(s) by the same method across different stimuli and ages. Surprisingly, no single study has yet firmly established the relative developmental primacy of different levels of inclusiveness in this way. Indeed, because this has not been done, the literature shows that the question of alternative ontogenetic trajectories of categorization inclusiveness remains an unsettled matter. Strong opinions have been offered on all sides. The first question we asked, therefore, was: Is there an identifiable developmental trajectory to hierarchical inclusiveness in categorization? In the following brief review, we include only studies that directly bear on the question because they compared (at least) two levels of structural inclusiveness. As mentioned above, L_y is a relative, not absolute, position in an inclusiveness hierarchy, and so a strong test of the preeminence of any L_y depends on comparing the same children's categorizing of L_y versus L_x and/or L_z.

It could be that children first categorize at more inclusive vis-à-vis less inclusive levels. Seeing or knowing that all of a kind (e.g., animals) go together and differ from other kinds (e.g., vehicles) seems the most straightforward categorization. The general schematic structure of L_1 categories is tied to fundamental knowledge we have about why entities exist and how they function. Using a sequential touching methodology, Mandler, Bauer, and McDonough (1991) reported that 18-month-olds distinguished more inclusive categories (animals and vehicles) without yet clearly differentiating less inclusive categories in the same domains, and Mandler and McDonough (1993, 1998a) later reported that 9-month-olds categorized animals and vehicles but not less inclusive distinctions within these two categories. Younger and Fearing (2000), familiarizing infants with members of two categories, observed that 7-month-olds only categorized at L_1 (cats vs. cars), but 10-month-olds categorized at L_2 (cats vs. birds). Using a visual preference technique, Quinn and Johnson (2000) reported that 2- to 3.5-month-olds categorized more inclusive better than less inclusive entities: Infants formed a category representation for mammals that excluded furniture but did not form a representation for cats that excluded elephants, rabbits, or dogs. Using object examining, Pauen (2002a, 2002b) reported that 8-month-olds, too, categorized more inclusive but not less inclusive sets. Setting aside methodological differences and associated age interactions, these results taken together are consistent with the idea that children first represent relatively more inclusive categories. So, children might first categorize L_1 versus L_2 or L_3. It is by no means a given that children should first possess L_1 categories, however. L_1 categories share general frameworks or functions rather than specific features (Markman & Wisniewski, 1997), generalities that are usually abstract and relate to the overall place of entities in the category. This is what is captured by general domain knowledge, which is often asserted to be beyond the ken of babies (Haith & Benson, 1998). Abstract categories have traditionally been considered a late developmental achievement just because they are so difficult to define in this way (Haith & Benson, 1998; Rosch & Mervis, 1975; E. E. Smith & Medin, 1981). Thus, the achievement of L_1 categorization by young children might pose considerable developmental challenge.

Indeed, ethnobiologists contend that L_2, a middle level of inclusiveness, actually occupies a psychologically privileged taxonomic position that best captures categories readily found in nature and affords the fundamental constituents in systems of folk-biological categorization, reasoning, and use (Bulmer, 1974; Ellen, 1993; Hunn, 1982). This often-called basic level is thought to be the rank of greatest object differentiation in the environment: Within-category variability is supposedly tighter for L_2 than for L_1 categories (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). It could be, then, that categorizing at L_2 is the easiest to acquire, most cognitively efficient, and primary in development (Rosch, 1978) and so might be more fundamental than more (L_1) or less (L_3) inclusive categories. Numerous studies using a wide variety of materials and methods have supported an L_2 advantage in children. Vygotsky (1962) believed that children form their first concepts at a middle level of generality. Mervis and Crisafi (1982) created artificial categories that fit a taxonomy of L_1, L_2, and L_3: Children were at ceiling for L_2 categories as young as 2.5 years of age, but they did not get the L_1 task correct until age 4 and the L_3 task until age 5.5. Mandler and Bauer (1988) observed that 12- to 20-month-olds alike categorized first at middle levels of inclusiveness, whereas only 20-month-olds succeeded at higher levels of inclusiveness; later, Bauer et al. (1995, Table 2) reported that 13-month-olds categorized middle-level but not more inclusive category prototypes, and 16-month-olds categorized middle-level but not more inclusive nonprototypes. Likewise, Waxman and Markow (1995) found that 12- to 13-month-olds differentiated L_2 contrasts (cars–airplanes; cows–dinosaurs) but not L_1 contrasts (animal–vehicle; tool–animal). Behl-Chadha (1996) was unable to show categorization of pictures of furniture as different from pictures of vehicles in 3-month-olds, although these infants distinguished pictures of tables from chairs or beds. When shown pictures of frogs on leaves (and monkeys on rocks), children as young as 15 months appear to retain information about specific categories and their properties that is brought to bear on their later task performance; it is hypothesized that children's learning in this way is guided not by a broad undifferentiated concept of animal or animates but rather by specific basic-like kinds (Furrer & Younger, 2008). Children's first lexical productions tend to be basic level nouns (Mervis, 1987). Thus, much anthropological, cognitive, and developmental work supports the primacy of middle-level (L_2) categorization (see also Fulkerson & Haaf, 2006; Mervis, 1987; Mervis & Rosch, 1981; Murphy, 2002):

> Research in both language acquisition and categorization converges on the precedence of basic-level words and basic-level categories . . . . children can categorize and label objects at the basic level . . . long before they can do so at other levels. (Liu et al., 2001, p. 1674)

Most investigators suppose that even less inclusive (L_3) categories likely emerge after more inclusive (L_1 or L_2) categories (Mervis & Crisafi, 1982; Waxman, Lynch, Casey, & Baer, 1997). However, some have argued that children's symbolic understanding in different domains develops in a progression from concrete to abstract (Deacon, 1997; Homer & Nelson, 2005; Peirce, 1955). There is evidence that atypical exemplars of a category are categorized faster at a more differentiated (subordinate) level than at a less differentiated (basic) level (Jolicoeur, Gluck, & Kosslyn, 1984; Murphy & Brownell, 1985), and more concrete and simpler concepts can be easier to learn than more abstract and complex concepts (Feldman, 2003). Thus, specific-to-abstract progressions can be found: For example, infants recognize relations of above or below or between before they generalize these relations to novel forms and reproduce them as categories (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003; Quinn, Polly, Furer, Dobson, & Narter, 2002). Tzeltal (Mexican Mayan) children reportedly first learn the names of plants corresponding to English subordinate-level categories and only later acquire more inclusive basic-level names (Stross, 1973).

If children at first possess L_1 categories, development afterward would presumably consist of differentiating less and less inclusive levels, following a variant of Werner's (1948) orthogenetic principle of development from global and undifferentiated to specific and articulated (see also J. J. Gibson & Gibson, 1955). If children categorize L_2 first, development afterward might then consist of grouping together middle-level categories to form more inclusive (L_1) categories and of differentiating middle-level categories into less inclusive (L_3) categories (Mervis, 1987; Rosch et al., 1976). It is also possible that categorizing at L_1 and L_2 emerges at the same time, as infants appear to be good at extracting correlations among attributes, and this ability could underlie category formation at different levels of inclusiveness (Quinn, Johnson, Mareschal, Rakison, & Younger, 2000; Younger & Cohen, 1986). Finally, if children at first possess L_3 categories, development afterward would presumably consist of aggregating to more and more inclusive levels.

The present study addresses the questions of at what level children first categorize and how categorization at other levels unfolds. Any consensus on such central developmental questions in structural categorization will remain conjecture in the absence of a single comprehensive study of categorization at multiple levels of inclusiveness, preferably across multiple domains with multiple stimuli at multiple ages, all using a single method (all of which we do here). Multiple levels of inclusiveness are required to address the relative advantage of more versus less inclusive levels, and three levels of inclusiveness are preferable to two. We tested three levels. Furthermore, to compare levels of inclusiveness, the tested contrasts must come from the same domain (Mandler & Bauer, 1988). Multiple domains are necessary to evaluate the generalizability of any putative ontogenetic trajectory, and multiple stimuli are requisite to circumvent some categories and stimuli at the same putative level of inclusiveness being intrinsically easier or more difficult for children than others (possible specialized processing mechanisms for one domain, e.g., animals, could result from built-in responses to features, e.g., faces versus nonfaces, that could privilege animal categorization; M. H. Johnson & Morton, 1991). To assess the generality of our findings, we tested children with different stimuli in four domains (animals, vehicles, fruit, and furniture). Multiple ages are needed to identify a developmental progression. We tested children of four ages. Finally, use of a single method across ages is called for because, as the foregoing review attests, different methods are known to yield varying categorization results.

Perceptual Attribute and Children's Categorization

Central to categorization is that the categorizer accepts as members of one category entities that are discriminable. That is, objects in the same category may not share all perceptual attributes, such as color and shape. As a consequence, perceptual attributes of objects in categorization are of more than passing effect. Therefore, our second question was: What is the role of perception in children's categorization of objects? To examine the role of perceptual attribute in young children's categorization, we studied different perceptual contrasts (low vs. high) within a single level of category inclusiveness (L_2). In a high-contrast condition, we tested children with stimulus contrasts with high within-category similarity and low between-category similarity (in the animal domain, e.g., differently sized and colored frogs and cows). In a low-contrast condition, we tested children with stimulus contrasts with high within-category similarity and high between-category similarity (in the animal domain, e.g., similarly shaped and colored dogs and horses). In brief, we varied perceptual attributes, holding level of category inclusiveness constant to isolate and identify the role of different levels of perceptual contrast in children's early object categorization.

Task and Analytic Method in Studying Children's Object Categorization

To employ a single categorization method with children ages 12 to 30 months, we used sequential touching (Mandler, Fivush, & Reznick, 1987). When children are presented simultaneously with a collection of objects from two categories (e.g., four animals and four vehicles) and their patterns of touching are recorded, the empirical observation is that, if children recognize a categorical distinction amongst the objects, they touch those from within a category in succession more than would be expected by chance. Sequential touching has the advantage that it can be used over a wide age range, diversity of objects, and variation in category level. Sequential-touching tasks thus provide an unconstrained robust methodology with which to study children's early spontaneous categorization.

Young children's sequential touching has been analyzed by group and by individuals. In group analyses, mean run length is the usual measure (e.g., Mandler et al., 1987). Run length is the number of touches in a row to objects from the same category. A run can range from one (if the child touches only one object from one category before touching an object from another category) to the total number of the child's touches (if the child touches only objects from one category). The mean of all run lengths is calculated. When children as a group touch objects from the same category at run lengths greater than chance, the inference follows that children as a group categorize.

Although run length provides key information regarding whether children as a group categorize objects, run length does not indicate whether individual children categorize objects from one or both categories. For example, one child might touch three of four horses but only one dog and still produce a high mean run length, showing an overall high level of categorization. However, this child's categorization performance is less sophisticated than that of a second child who touches all the horses and all the dogs each in a sequential manner. The first child categorized horses, but the child's touching leaves in question his/her categorizing of dogs. An additional approach to evaluate categorization, therefore, is to focus on individual children, where the question is whether and how each child categorizes. The third question that motivated this research, therefore, was: How do group versus individual analyses of children's categorization compare? We systematically evaluated and report group and individual analyses of the same children's categorization.

Overview

In an effort to address several still-outstanding questions about the development of the inclusiveness structure of object categorization, in one study we explored the nature and early development of children's categorizing multiple objects at multiple levels of category inclusiveness, and we did so in four object domains in children of four ages. The most inclusive categories we used (L_1) contrasted animals, vehicles, fruit, and furniture (see Table 1). We tested three levels of hierarchical inclusiveness so as to be clear about the pattern of possible findings with respect to a nested hierarchy, and we used four domains to assess the generality of the findings. Children can respond to idiosyncratic differences between toys representing the particular category contrast being tested, and these differences may not be diagnostic or representative of broader category distinctions. To assess categorical responding on surer footing, we sampled from a broad array of category exemplars. We also measured two degrees of perceptual contrast at a middle level (L_2) of inclusiveness. We asked whether children would categorize high-contrast before low-contrast objects, even though they appeared at the same level of category inclusiveness. In all cases, we drew our tests of child categoriza-

Table 1
Category Exemplars Used for Each Category Domain

Category level	Animals	Vehicles	Fruit	Furniture
L_1	duck, lion, pig, porpoise	boat, sedan, tractor, truck	lime, peach, pear, watermelon	bookshelf, desk, grandfather clock, sideboard
L_2 high contrast	frogs–cows (different colors and breeds)	helicopters–pickup trucks (different colors)	bananas–grapes (various sizes and colors)	beds–tables (various sizes and colors)
L_2 low contrast	dogs–horses (different breeds; similar colors)	SUVs–panel trucks (different colors)	apricots–lemons (various sizes and colors)	couches–easy chairs (various sizes and colors)
L_3	sharks (mako and hammerhead)	sports cars (convertibles and hard tops)	red apples (Delicious and Winesap)	chairs (straight-back and high chairs)

tion from the same category domains. Analyses compared sequential touching to explore questions surrounding child development, category level inclusiveness, and perceptual contrast. In addition, we compared group and individual analyses of children's categorization.

Method

Participants

Twenty 12-month-olds (*M* age = 12 months 7 days, *range* = 12 months 2 days to 12 months 14 days), twenty 18-month-olds (*M* age = 18 months 7 days, *range* = 17 months 24 days to 18 months 14 days), twenty 24-month-olds (*M* age = 24 months 7 days, *range* = 23 months 15 days to 24 months 10 days), and twenty 30-month-olds (*M* age = 30 months 7 days, *range* = 29 months 14 days to 30 months 14 days) participated. Approximately equal numbers of girls and boys were tested at each age; the sample was predominantly European American, with approximately 10% of the children of African American, Asian American, and/or mixed ethnicity. Families were recruited via purchased mailing lists identifying new families in a greater metropolitan area, and they all came from middle to upper socioeconomic status households ($M = 58.3$, $SD = 6.2$, on the Hollingshead [1975] Four-Factor Index of Social Status; see Bornstein, Hahn, Suwalsky, & Haynes, 2003). Children had been healthy and term at birth and were healthy at the time of testing. An additional 36 children began testing, but their data were not included due to fussiness or other procedural failures (*n*s = 13 at 12 months, 5 at 18 months, 6 at 24 months, 2 at 30 months), experimenter error (*n*s = 2 at 12 months, 1 at 18 months, 3 at 24 months), or parental interference (*n*s = 1 at 12 months, 1 at 18 months, 2 at 24 months).

Materials

Object characteristics. Small naturalistic three-dimensional scale models were used to create 14 sets of stimuli (see Table 1). The replicas averaged 9.15 × 4.93 × 5.74 cm.

Within-category discrimination of objects. Some objects used in the current study (dogs and horses at L_2) and others showing even finer discriminations (different breeds of cats at L_3) have been shown to be discriminable by children as young or younger than those studied here (e.g., 3 to 4 months in Quinn, 2004). Kovack-Lesh and Oakes (2007), for example, used almost the exact same pairing of dogs and horses as we did for the animal $L_{2\ \text{low contrast}}$ comparison, and 10-month-olds discriminated within categories. Nevertheless, we conducted within-category discrimination tests in an independent sample of children the same age as our youngest participants, using a variant of the object examining procedure (Oakes, Madole, & Cohen, 1991). Each child was given eight 30-s trials. Children were initially presented with six familiarization trials in which they were allowed to examine a single object (e.g., a dolphin). Following familiarization, children received two test trials. A novel test trial consisted of another exemplar from the same category (e.g., a duck). A familiar test trial was a seventh presentation of the familiar object (e.g., the dolphin). The dependent variable was time engaged in object examining. The stimuli were two types each of animals, vehicles, fruit, and furniture. Altogether, 12 twelve-month-olds participated, and children were tested in two to four tasks as long as they remained attentive (*n*s = 8 for animals, 10 for vehicles, 9 for fruit, and 6 for furniture). The tasks were randomly assigned, as were the exemplars used during familiarization and test and the order of the test trials. A 4 × 2 mixed design analysis of variance (ANOVA) with domain as between subjects (even though children were tested with up to four domains) and trial as within subjects (mean of the first three trials, mean of the last three trials) confirmed that children declined in examining during familiarization; main effect for trial, $F(1, 29) = 39.22$, $p < .001$, partial $\eta^2 = .58$ (*M* first three trials = 10.37 s, $SD = 3.16$; *M* last three trials = 4.79 s, $SD = 2.43$). A 4 × 2 ANOVA with domain (animal, vehicle, fruit, furniture) and test trial (novel, familiar) confirmed that children examined the novel ($M = 17.81$ s, $SD = 7.93$) more than the familiar object ($M = 7.77$ s, $SD = 6.09$), $F(1, 29) = 45.34$, $p < .001$, partial $\eta^2 = .61$. For both analyses, no main effects or interactions with domain emerged, all $Fs(3, 29) < 2.15$, *ns*. Failing to remove within-subject variation from the error term risks failing to detect a significant group difference; however, these analyses focused on assessing discrimination of objects within domains (the trial factor) rather than between domains. In sum, even the youngest children participating in this study discriminated exemplars in each of the categories used.

Sequential Touching

Procedure. The child sat at a small table, either on a parent's lap or alone in a chair (in which case the parent sat behind the child). The experimenter sat opposite the child. A 74 × 33 cm white vinyl-covered tray was placed on the table in front of the child, enabling the simultaneous presentation of all objects. A camera positioned behind the experimenter focused on the child's torso and recorded the child's actions with the objects on each trial.

Children were tested in either an animal–vehicle or fruit–furniture condition. The order of presentation of seven stimulus sets each child received was randomly determined. On each trial, the experimenter informally and randomly positioned eight objects (four from each domain) on the tray in front of the child. Categorization is enhanced by simultaneous category presentation (Oakes & Ribar, 2005). Care was taken so that no more than two objects from the same domain were in the same immediate location. After placing the tray on the table within easy reach of the child, the experimenter gave the standard prompt, "These are for you to play with." Children were allowed to manipulate the objects in any way they wished for 2 min with no further prompting. If a child did not touch any of the objects after 10 s, the experimenter repeated the original prompt; if the child lost interest during the session, the experimenter encouraged the child's attention back to the objects by saying, "These are for you to play with." If an object fell off the table, the experimenter (or parent) unobtrusively replaced the object on the tray.

Scoring. Videorecords were coded randomly by a single coder who was naive to the hypotheses of the study. The order in which the child touched objects was coded. For a contact to be counted as a touch, the child needed to have been looking at the object as the child's hand approached and contacted it. Touches were calculated with replacement, and an object could be touched more than once, except for two touches of the same object in succession. A touch was also recorded if the child used one object intentionally to contact another (e.g., touch the truck with the frog). A second coder who was also naïve to the hypotheses coded a random sample of 25% of the sessions to obtain a measure of coding reliability for touches. Agreement was based on each object contact, and a value reflecting percentage of agreement was calculated for each set for each child. Mean agreement was 90% (range = 86%–94%). From this scoring the total number of touches to each set of objects and the order of objects and domains sequentially touched were derived for group analyses.

To assess individual categorization, we calculated the percentage of children in a group who were categorizers, using a procedure outlined by Mandler et al. (1987) and a Monte Carlo program developed by Dixon, Woodard, and Merry (1998). Individual children were identified as categorizers if they showed sufficiently long run lengths that included three or four different objects from one of the two domains presented. Because a run of touching multiple unique objects in a row can occur by chance, especially when a child makes many touches, the Monte Carlo program determines the likelihood of occurrence of runs. Specifically, the program computes how often categorizing runs occur in 10,000 random draws. Repetitions are allowed (excluding touches to the same objects in immediate succession) as long as a run includes three or four unique objects. This technique estimates the probability of one or more categorizing runs occurring by chance, as a function of the total number of objects a child touches.

Results

Preliminary analyses assessed the effects of gender and category domain (animals, vehicles, fruit, furniture); no main effects or interactions were found between girls and boys or across category domains. All analyses therefore collapsed across gender and category domain.

Mean Run Length (Group Analyses)

Table 2 shows the mean run length for each age at each level of category inclusiveness compared with chance performance. Given the hierarchical nature of the design (see Table 1), that the same children did not participate in the same number of sets at all levels (they completed one set at L_1 and two sets at each of the remaining levels), and that we were interested in whether children at each age at each level categorized, we followed the tradition of testing children's mean run length in each cell against chance (e.g., Mandler et al., 1987). The mean run length values show several patterns highlighted in Table 2: (a) Mean run length at the most inclusive level (L_1) exceeded chance for all age groups; (b) significant mean run lengths at the middle level of category inclusiveness (L_2) varied by age and perceptual contrast, with mean run lengths exceeding chance for high contrasts developmentally earlier than for low contrasts; and (c) mean run lengths at the least inclusive level of categorization (L_3) never exceeded chance at any age. Our cross-sectional group findings indicate that children consistently categorize more inclusive levels before less inclusive levels and high contrasts before low contrasts.

Motor development. It is possible that children's developmental patterns of sequential touching were an artifact of the growth of their reaching abilities. Reaches might change in spatial distribution with age. Although the youngest children were 12 months of age, they still might not possess the coordination to

Table 2
Run Lengths and Associated t and p Values at Different Levels of Categorization by Children of Different Ages

	Child age											
	12 months			18 months			24 months			30 months		
Category level	*M*	*SD*	*t*	*M*	*SD*	*t*	*M*	*SD*	*t*	*M*	*SD*	*t*
L_1	**2.45**	**1.51**	**1.71**†	**2.47**	**1.31**	**2.57***	**2.47**	**1.27**	**3.27****	**2.80**	**2.02**	**3.09****
L_2 high contrast	**2.49**	**2.69**	**2.55***	**2.47**	**1.37**	**3.60****	**2.63**	**1.20**	**5.87****	**2.76**	**1.59**	**4.21****
L_2 low contrast	1.94	1.29	0.66	2.07	1.30	1.60	1.93	0.61	1.20	**2.31**	**1.61**	**2.33***
L_3	1.95	1.40	0.69	2.01	1.04	1.30	1.91	0.65	1.07	1.81	0.57	0.25

Note. Bold cells show conditions where children as a group categorized.
† $p < .10$. * $p < .05$. ** $p < .01$, two-tailed.

reach and manipulate all of the objects due to immaturities of the motor system or other physical limitations (Adolph & Berger, 2005), possibly leading to less sophisticated sequential touching among younger vis-à-vis older children. In short, patterns of touching that we attribute to the development of categorization could be ascribable to the development of children's motor skills. To address this possibility, we investigated (a) age differences in the number of objects touched and (b) whether the number of children who touched all four objects in each domain systematically varied (increased) with age. For each level of category inclusiveness, the total number of touches was analyzed in a one-way ANOVA with age as a between-subjects factor. Mean numbers of touches by age and inclusiveness level varied over a small range (12.2–18.9). Although two significant differences among ages emerged—$L_{2\ \text{high contrast}}$, $F(3, 156) = 4.36$, $p < .01$, partial $\eta^2 = .08$; $L_{2\ \text{low contrast}}$, $F(3, 156) = 3.43$, $p < .05$, partial $\eta^2 = .06$—differences in the mean numbers of touches did not mirror the systematic patterns revealed by children's sequential touching. For example, in the $L_{2\ \text{low-contrast}}$ sets, Table 2 shows that only 24- and 30-month-olds produced significant mean run lengths. If this result was based on motor maturity, we would expect the numbers of touches to be significantly different for older compared with younger children. However, 12-month-olds showed the same numbers of touches as 30-month-olds, and 18-month-olds showed fewer touches compared with 12-month-olds (as determined by Tukey-b post hoc tests). Next, chi-square analyses were used to investigate whether the number of children who touched all four objects in one or both domains in each task varied across age. Cell frequencies ranged from nine to 20 children, but no differences were found across ages, χ^2s (three for L_1 and six for L_2 and L_3) = 0.08 to 6.30, *ns*. In addition, all objects in each set were placed in easy reach for each child; indeed, phenomenologically, objects in this situation have a greater presence for children than adults (see Figure 1). Finally, the youngest children (12-month-olds) categorized L_1, so motor development status was not a limitation. In sum, the age and category level findings do not appear to be an artifact of motor development in children.

Fatigue. It is also possible that children's patterns of touching were influenced by the number of tasks. Because we wished to compare multiple category levels and category domains in the same children, in this study the number of categorization sets presented to each child (seven) was somewhat greater than that typically used (three to five). In anticipation of the possibility that children might become fatigued over the course of the study in any way that could systematically influence their run length, we randomized presentation of category sets across children. In addition, to test formally for possible fatigue, we compared mean run lengths between children who received the same category sets as their first, second, sixth, or seventh test sets. A 4 × 4 ANOVA was conducted with age (12, 18, 24, 30 months) and order (first, second, sixth, seventh) as between-subjects factors. The analyses revealed no main effects or interactions. In sum, the age and category level findings do not appear to be an artifact of children's fatigue across the seven tasks.

Between-domain discriminability. The exemplars in the L_3 domains possessed the highest between-category similarity, and it is possible that children failed to categorize because they were unable to discriminate between the two categories in a domain. In other words, children may not have discriminated convertible

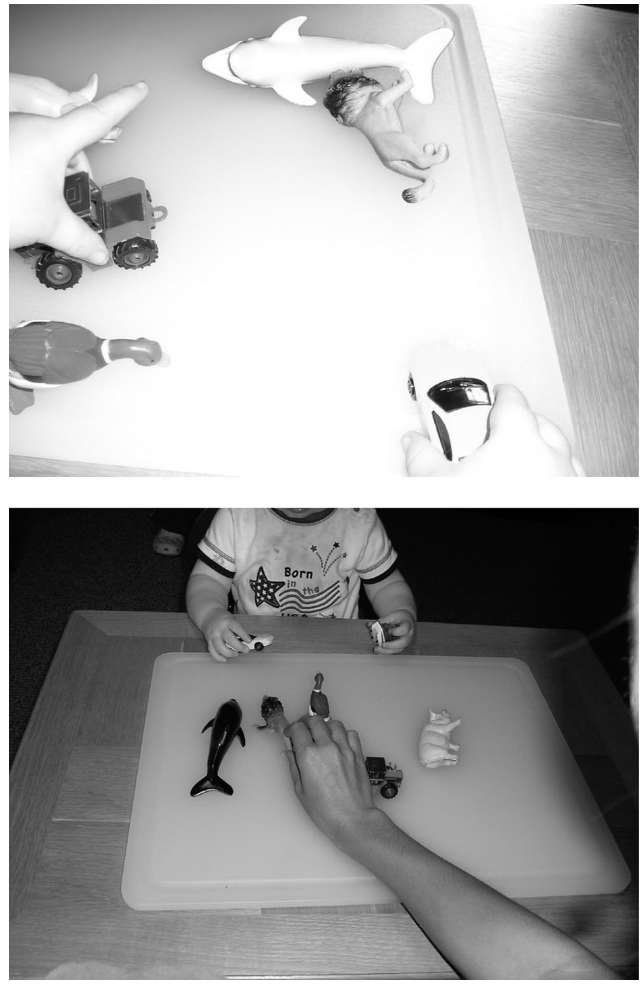

Figure 1. Top: A child's eye view of the objects in the categorization task. Bottom: An adult's eye view of the objects in the categorization task.

sports cars from hardtop sports cars, and so forth. To address this possibility, we tested an independent sample of children in an object examining procedure (described above). Following six familiarization trials of the same object (e.g., a convertible sports car), children were presented with a novel object (e.g., a hardtop sports car) and the same familiar object (the convertible sports car). Altogether, 36 eighteen-month-olds participated in two of the four conditions (sharks, cars, apples, and chairs) as long as they remained attentive (*n*s = 12 for sharks, 14 for cars, 15 for apples, and 13 for chairs). The conditions were randomly assigned, as were the exemplars used during familiarization and test and the order of test trials. A 4 × 2 ANOVA with domain (sharks, cars, apples, and chairs) and trial (mean of the first three trials, mean of the last three trials) confirmed that children declined in examining during familiarization, $F(1, 50) = 73.61$, $p < .001$, partial $\eta^2 = .60$ (*M* first three trials 14.37 s, *SD* = 5.30; *M* last three trials = 8.64 s, *SD* = 5.26). A 4 × 2 ANOVA with domain (sharks, cars, apples, and chairs) and test trial (novel, familiar) confirmed that children perceived the difference among objects between domains in that they examined the novel (*M* = 15.69 s, *SD* = 6.24) more than the familiar object (*M* = 5.61 s, *SD* = 5.78), $F(1, 50) =$

79.57, $p < .001$, partial $\eta^2 = .61$. No main effects or interactions with domain were found in either analysis (all Fs < 2.19, *ns*). In addition, closer analysis of our individual data (below) shows some children at each age categorize at the subordinate level, and therefore children must be discriminating subordinate categories. In sum, the failure of children to categorize at L_3 was not due to their failure to discriminate within categories.

Actions. Finally, it is possible that the object replicas we used did not activate the conceptual representations in children that we suppose they do. To address the question of whether children treated the replicas as conceptual representations of their real-world referents, we independently coded how children interacted with the objects (in addition to what objects the children touched). To this end, we generated a list of possible actions that were classified by adults as appropriate or inappropriate for each object domain. For example, animals touching feet to the tray as in walking movements was appropriate as opposed to mouthing the animal which was inappropriate; vehicles scooting or rolling across the tray as opposed to mouthing vehicles; mouthing fruit as opposed to scooting fruit across the tray; and moving furniture into an upright position as opposed to banging it into another object. Each child's actions on every contact with every object were assessed as appropriate or inappropriate. (A small number of children showed neither appropriate nor inappropriate actions; instead, their actions were exploratory in nature, such as holding, and they were not included in the analyses.) The number of appropriate actions was divided by the total number of appropriate and inappropriate actions. Across age, each proportion of appropriate actions was greater than chance (.50), with $L_{2\ \text{low contrast}}$ being marginally so: L_1, N of participants $= 70$, $M = 0.66$, $SD = 0.37$, $t(69) = 3.64$, $p < .01$; $L_{2\ \text{high contrast}}$, $N = 123$, $M = 0.59$, $SD = 0.44$, $t(122) = 2.34$, $p < .05$; $L_{2\ \text{low contrast}}$, $N = 127$, $M = 0.56$, $SD = 0.43$, $t(126) = 1.61$, $p = .055$; and L_3, $N = 117$, $M = 0.64$, $SD = 0.43$, $t(116) = 3.49$, $p < .01$. In sum, children acted with the replicas in appropriate ways.

Categorizer Classification (Individual Analyses)

Children were each classified as categorizers or noncategorizers for each domain in each set using Monte Carlo simulation (Dixon et al., 1998). Table 3 shows the percentages of children at each age classified as categorizers, collapsing across single and dual categorizers and stimulus sets. As with group mean run length, these percentages tended to increase with child age and decrease with decreasing inclusiveness of category; see marginal means for age across level (12 months $< 18 = 24 = 30$ months) and for level across age ($L_1 = L_{2\ \text{high contrast}} > L_{2\ \text{low contrast}} = L_3$), zs $=$ 1.80–4.91, ps $< .05$, one-tailed (Altman, Machin, Bryan, & Gardner, 2000). In terms of category levels, more than one-half of children at each age categorized L_1 and $L_{2\ \text{high-contrast}}$ sets, and only half or fewer children at all ages categorized $L_{2\ \text{low contrast}}$ and L_3 sets (except 30-month-olds $L_{2\ \text{low contrast}}$). That said, 46.25% of individual children of all ages (and 40% of 12-month-olds) categorized at L_3, where the mean run length analyses suggested that children as a group do not.

Discussion

This study addressed several open questions about inclusiveness, age, domain, perception, and analysis in young children's structural conceptualization of object categories. On the basis of sequential touching run lengths and categorizer classification, and holding method constant, we found that from 12 to 30 months of age individually and as a group children show regular developmental sequences in their categorization abilities: Girls and boys alike tend to categorize objects in a variety of different domains at more inclusive levels before less inclusive levels, and they categorize objects with high perceptual contrasts before low contrasts. Here we discuss each of these findings in turn.

Levels of Inclusiveness and Perceptual Attribute in Young Children's Object Categorization

In reply to the first question raised in the Introduction, our data support a global-to-specific trajectory in the development of category inclusiveness. In sequential touching, children categorize at more inclusive levels (e.g., animals or vehicles) before less inclusive levels (e.g., types of animals or vehicles) before even less inclusive levels (e.g., specific animals or vehicles). As a group, even the youngest children we studied (1-year-olds) categorized at the most inclusive level we evaluated, but even the oldest children (2.5-year-olds) did not categorize at the least inclusive level. The direction of these results for the earlier onset of more inclusive categorization in the second and third years of life is consonant with that from other studies that have approached object categorization via a variety of methods with children of the same and

Table 3
Percentages of Children of Different Ages Classified as Categorizers of Different Levels of Categorization

Category level	Child age: 12 months	18 months	24 months	30 months	*M*	*SD*
L_1	**55.00**	**75.00**	**80.00**	**65.00**	68.75	11.09
L_2 high contrast	**60.00**	**77.50**	**77.50**	**77.50**	73.13	8.75
L_2 low contrast	40.00	35.00	50.00	**57.50**	43.13	14.05
L_3	40.00	50.00	50.00	45.00	46.25	4.79
Combined *M*	48.75	59.38	64.38	61.25		
SD	10.31	20.45	16.63	13.62		

Note. Bold cells show conditions where more than 50% of individual children in the group categorized.

other age ranges. In one of the first reports in the field, Ross (1980) provided evidence for categorization of animals versus food versus furniture among 12-month-olds. Using a manipulation task, Mandler and colleagues (Mandler et al., 1987; Mandler & Bauer, 1988; Mandler & McDonough, 1993) showed that children in the first 2 years differentiate categories of animals and vehicles but not lesser inclusive distinctions, such as between dogs and horses. Results from generalized imitation studies also show that children represent more inclusive object categories before less inclusive ones (Mandler & McDonough, 1998a, 1998b; for parallel findings with younger children, see Quinn & Johnson, 2000; Younger & Fearing, 2000). Our study attempted to take the next step in this literature by assessing within the same children three levels of object category inclusiveness across four category domains using a single procedure. Contemporary opinion is thus converging on the notion that children first categorize objects at more inclusive (i.e., global or superordinate) levels and later at less (i.e., basic) and less (i.e., subordinate) inclusive levels (see Mandler, 2008).

Based on children's global categorizing, Mandler (Mandler, 1992, 1998) concluded that their categorizations represent concepts (L. B. Smith, 2000), and Younger, Johnson, and Furrer (2007) highlighted conceptual underpinnings of children's property generalizations. After watching an experimenter model a "plane drinking," 14- to 16-month-olds were as likely to (appropriately) select a swan as another plane to "give a drink." Children's choice of an animal to give a drink (despite the counterexample seen during modeling) implicates conceptual knowledge (see Sheya & Smith, 2006). The fact that children in our study categorized L_1 objects in four domains accords with this conclusion. The ability to form global or superordinate categories has been taken as a sign of "sensitivity to high-order taxonomic relations among stimuli" (Fenson, Cameron, & Kennedy, 1988, p. 897). This is because superordinate categories are thought to be linked less by perceptual and functional associations and more by abstract, conceptual connections (Mandler et al., 1991). However, Fenson et al. (1988) examined 26-month-olds' performance in match-to-sample tasks with superordinate and basic matches that varied in perceptual likeness. As here, children matched categorically related superordinate and basic pictures as long as a moderate perceptual likeness obtained between exemplars. Moreover, children were just as likely to make superordinate matches as they were basic matches. Our children also categorized high-contrast L_2 objects and did so as systematically as L_1. Fenson et al. interpreted their result to mean that even 2-year-olds' superordinate-level categories are perceptually bound and consequently that they are no different in kind from basic-level classes. If L_1 categories are not based on readily apparent perceptual similarities, and if children categorize objects at L_1, children must have access to more global category representations. The perceptual similarities that organize categories at L_1 (e.g., animals, vehicles, fruit, and furniture) are supposedly less encompassing than the similarities that organize categories at L_2 (e.g., dogs, trucks, apricots, and couches). Likewise, the work of Bornstein (1984) and Rakison and Butterworth (1998) supports a perceptual account of the global-to-basic shift and challenges the view that children necessarily appeal to conceptually based representations to underpin performance in the sequential-touching procedure. The contrasting findings from our L_2 high- and low-contrast sets comport with a perceptual account. When the perceptual similarity among items from two domains at the same level of category inclusiveness is high (and thus low in contrast), only the oldest children showed evidence of categorization.

Why Is There a Developmental Trajectory?

Our findings point to a developmental trajectory across different levels of category inclusiveness: Both group and individual analyses show more inclusive categories earlier and easier, and less inclusive categories later and harder. Why does the development of categorical structure follow a more inclusive to less inclusive path? Different answers to this question have been proposed.

Motor or representational development? We earlier addressed a possible motor development account of these findings. Differences in children's mean numbers of touches did not mirror the patterns revealed by their sequential touching scores; the number of children's touches was not systematically related to their age or to category level; nor were any differences found across age in the numbers of children who touched all objects. All objects were within reach of children in all age groups, and, notably, even the youngest (12-month) children categorized at the most inclusive (L_1) level and the oldest children selectively failed at the least inclusive level (L_3). So motor development per se cannot be said to govern children's changing categorizations.

In this study, we asked young children to categorize small replicas of real-world objects. The use of such models is longstanding accepted practice in the field (Ellis & Oakes, 2006; Mandler, et al., 1987; Mareschal & Tan, 2007). To draw conclusions about the nature of children's categorization, we assumed that children at some level understand that the replicas represent real objects and that children categorize replicas of real objects as they would the real-world referents. Could it be that children's progressively achieving symbolic understanding accounts for the developmental trajectory? It has been argued that a challenge to achieving insight into symbols is their dual nature (J. J. Gibson, 1979) or double reality (Gregory, 1970; see also Langer, 1942; Saussaure, 1959): To understand the symbolic nature of a model requires simultaneously acknowledging both its physical existence and its representational aspect. It could be that the kinds of replicas we used were not understood by children to represent their real-world referents, and it is only as symbolic capacity develops that children grow in their categorization ability.

Symbolic relations come in several flavors: Indices connect to their referents through some physical or causal link (e.g., fingerprints indicating the presence of a person), and symbols connect to their referents through arbitrary agreement among those who use them (e.g., the word *cat* referring to a specific type of animal). In this study we used icons, a third relation and the most direct. Icons connect to their referents through perceptual similarity (here qua scale model). Index- and symbol-referent relations are arbitrary and difficult to learn; by contrast, icons are highly representative (Peirce, 1955) in that they closely physically resemble what they signify. As long ago as 1890, William James argued that the "principle of sameness" is so basic to mental life that it figures in the most primitive intellectual activities, and Deacon (1997) posited that iconic representation is the basis of all representation. The more the symbol and referent share in their perceptual similarity, the more transparent the referential relation between them and the greater the likelihood that children will transfer information between them (Callaghan, 2000; DeLoache, Kolstad, & Anderson, 1991; Ganea, Pickard, & DeLoache, 2008). Higher levels of iconicity involve more perceptual detail and hence more information in common between replicas and real objects. Our replicas shared near exact physical resemblance with their real-world referents (including color, shape, sometimes texture, relations among components, and so on), and children explored our stimuli visually and tactually, enhancing their multimodal affordances (J. J. Gibson, 1979). In the view of semiotic theoreticians (Peirce, 1991), icons' similarity to their referents evidences their primacy in development and cognition.

The empirical literature also supports young children's understanding of replicas. Nine-month-olds already manually explore pictures in books; they feel, rub, even grasp at the pictures as though they were real objects (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998), and they engage in more manual exploration of highly iconic pictures (photographs) than less iconic pictures (drawings; Pierroutsakos & DeLoache, 2003). The defining component of pretense is the performance of activities in an "as if" mode (Hickling, Wellman, & Gottfried, 1997; Lillard, 2002), and infants' manual behavior toward pictures reflects a response to depicted objects as if they were real. Moreover, even children older than we studied possess iconic realism in evidence when 3-year-olds report that even a picture (a 2D representation less iconic than our 3D replicas) of an ice cream cone will be cold to the touch (Beilin & Pearlman, 1991) or that jiggling a picture of blocks would trigger the blocks falling (Flavell, Flavell, Green, & Korfmacher, 1990) or that objects in a photo would vary if real objects were changed and vice versa (Robinson, Nye, & Thomas, 1994; Zaitchik, 1990). The developmental literature is rife with other apt examples. After engaging in a series of play episodes with real toys or their pretend substitutes, 3- and 4-year-olds (again, children older than those in the present study) incorrectly claim that they played with the real toys when they actually carried out their actions with the pretend substitutes (Foley, Harris, & Hermann, 1994). After watching an adult pretending to bathe two dolls and "dry" one of them, 20-month-olds reasoned that the other doll was still wet and dried it themselves (Walker-Andrews & Kahana-Kalman, 1999). Preissler and Carey (2004) taught 18- and 24-month-olds a new label (*whisk*) for a line drawing of an unfamiliar object. When the children were subsequently shown the drawing paired with the real object and asked to indicate the whisk, all of them chose either the object alone or the object and its picture. They never selected the picture alone, even though they had learned the label for it. Thus, 18-month-old children who hear a new word in relation to a picture of an object appreciate that the word (symbol) refers to the real object, not simply to its picture. Relatedly, Younger and Johnson (2004) observed that 14-month-olds (near the youngest age we studied) comprehend the representational relation between miniature toy replicas and their real object counterparts. Preissler and Carey (2004), who also studied children's understanding of replicas, pictures, and words, observed no differences in 18- to 24-month-olds' responses to real items and toy models. Moreover, the "scale errors" that children between 15 and 30 months commit with little replicas, such as actually trying to enter a little model toy car (DeLoache, Uttal, & Rosengren, 2004), make it abundantly clear that at some level even children exactly in our age range seriously treat even a tiny replica car as something that one actually rides in (Ware, Uttal, Wetter, & DeLoache, 2006). In sum, toy animals without some specific perceptual attributes (say, an odor) and without some specific conceptual attributes (say, the ability to direct their own behavior) nevertheless appear to activate stored mental representations of real-world animals that have corresponding perceptual and/or conceptual attributes (Pauen, 2002a, 2002b; Ware et al., 2006), and the more similar a small object is to the large version of it, the more strongly the child's representation of the real object will be activated by the replica.

These conclusions are further buttressed by a vast literature in the development of symbolic play (Bornstein, 2007; Göncü & Gaskins, 2007; McCune, Dipane, Fireoved, & Fleck, 1994). Around 1 year of age (also the youngest age we studied), a major change in the complexity and quality of play occurs, as children begin to engage with replicas in the way their real-world referent objects are used (e.g., rolling a toy car on its wheels across the floor). Consonant in this regard, our action analyses showed that the children in this study interacted with the replica objects in appropriate ways more than inappropriate ones.

Finally, in this study if representational development per se undergirds children's categorization performance, then the onset or acquisition of a kind of "representational insight" would predict their categorizing all levels of inclusiveness at that point. As Table 2 shows, however, 18- and 24-month-olds as a group categorize L_1 and $L_{2\ \mathrm{high\ contrast}}$, but not even 30-month-olds categorize L_3. As a consequence, it is unlikely that pure failures of representational capacity inhibited children in this study from categorizing at different levels of inclusiveness or that general representational development accounts for the ontogenetic trajectory in category inclusiveness that we observed.

Why start at L_1? Efficiency of processing. Hierarchical inclusiveness appears to be a property of all cultures' categorical structure of the natural world (Berlin, 1992). Most objects can be thought of as falling in a set of hierarchically inclusive categories, ranging from general (e.g., animals) to specific (e.g., collies), so every object as well as any unknown object is automatically a member of some maximally general (L_1) category. Perforce, then, more inclusive categories occur with greater frequency than do less inclusive categories. There are more animals in the world than there are dogs, more dogs than collies. Therefore, categorization at more inclusive levels maximizes accuracy of classification. More inclusive categories also have higher cue validity, a metric of within-category similarity relative to between-category similarity (Murphy, 2002). It is normally easier to distinguish animals from vehicles than it is to distinguish two kinds of animals. Because more inclusive categories include less inclusive categories, the cue validity of more inclusive categories can never be lower than that of the categories they include. For nested categories, cue validity will therefore always be higher for a more inclusive category than any category it subsumes. Moreover, the pervasive IS-A categorical relation is asymmetric. A dog is always an animal, but all animals are not dogs. Thus, category relations are transitive: All collies are dogs, and all dogs are animals; therefore, all collies are animals. The transitivity of category membership leads to a similar transitivity of property inheritance (Murphy, 2002). Nearly every property true of the members of a more inclusive category also tends to be true of the category's less inclusive levels. Knowing that animals (L_1) breathe implies that dogs (L_2) breathe, collies (L_3) breathe, and so on. Hierarchical inclusiveness provides for the inheritance of properties, so possessing L_1 knowledge obviates the necessity to store large numbers of individual facts. The corollary of property inheritance is especially useful for generalizing new facts about a more inclusive category to a less inclusive one. Without such ability, learning facts about the world would be much more daunting. In sum, higher levels of inclusiveness carry multiple forms of cognitive economy, and even though young children may not have the hierarchy stored in memory, they can use the information about category inclusion to arrive at many correct inferences. Neurological evidence too supports the primacy of L_1. Ribot's law of retrograde amnesia (Hodges, Graham, & Patterson, 1995) holds that the dissolution of memory is inversely related to the recency of the event. L_1 categorization is so fundamental that it is the last to be lost in cases of semantic dementia and other cognitive degenerative diseases. Even when patients no longer know the difference between dogs and cats, they still regard both as animals (Hodges et al., 1995).

To be fair, some arguments in support of the numerous advantages of starting at L_1 appear post hoc, but that in no way negates the veracity or force of these explanations or mental life starting out with the real advantages of L_1 categories. In any event, L_1 is not a universal advantage. Although many properties inherent to L_1 also inhere to L_2, a serious developmental challenge is posed by the fact that some properties typical of L_1 are not necessarily typical of all L_2 or L_3 (e.g., birds typically fly, but penguins do not). Perceptual information might suffice children to form an L_1 category representation inclusive of at least prototypical animals. However, conceptual information is necessary for children to group together perceptually diverse mammals (whales and bats) and animals more generally (Mandler & McDonough, 1993). Even children with L_1 capabilities still have much to figure out, and some conceptual thinking must guide children's categorization (Mandler, 2000; Premack, 1990).

What happens next in development? Differentiation theory. One key characteristic of acquiring knowledge in a domain is the ability to make finer differentiations among initially broad conceptions (E. J. Gibson, 1969; Keil, 1989; Mandler, 1992). As Mervis and Crisafi (1982, Experiment 2) learned, the more obvious the categorization scheme becomes, the more differentiated are the categories. Differentiation theory (J. J. Gibson & Gibson, 1955; Werner, 1948) predicts a trajectory of category development from more to less inclusive that aligns with the developmental pattern of results we found. Children's property generalizations are guided by conceptual representations that initially are broad in scope (e.g., animates, inanimates; Gelman & Opfer, 2002; Poulin-Dubois, Frenkiel-Fishman, Nayer, & Johnson, 2006; Rakison & Poulin-Dubois, 2001), and these concepts become more differentiated over developmental time (Mandler, 2004). Thus, as children grow, they appreciate more and more subtle attributes of objects that enable them to categorize accurately at more and more distinctive levels. In the same vein, Mandler (2008) stressed that early concepts (conceptual categories) are global in nature and that conceptual learning consists in large part of differentiation of broad, often vague notions into finer, more detailed concepts. However, differentiation theory raises a further question: On what basis does differentiation proceed?

Several possible answers to this question present themselves. First, changing properties of visual system function could underpin developmental differentiation. Mandler (2008) speculated that the low-pass characteristic of the young infant's visual system might support global category superiority if some of the fine-grained featural values that differentiate basic- or subordinate-level categories from the same global category were not resolvable. This explanation is improbable with children older than 1 year (Quinn et al., 2000). Furthermore, 40% of 12-month-olds successfully categorize even at L_3.

Second is perceptual development. At a given level of categorization, entities within a category tend to be more similar to one another than to entities outside a category. Indeed, E. E. Smith and Medin (1981) concluded that similarity might be the best general heuristic for determining category membership. Perceptual experience with objects or categories could be the best teacher. Results from perceptual contrasts in the present study contribute to the tenability of a perceptual interpretation. We systematically varied perceptual contrast (holding level of category inclusiveness constant) to isolate and identify the effects of different levels of perceptual contrast on early categorization. In a high-contrast condition, we tested children with high within-category similarity and low between-category similarity (e.g., in the animal domain, frogs versus cows); in a low-contrast condition, we tested children with high within-category similarity and high between-category similarity (e.g., in the animal domain, dogs versus horses). As a group, children categorized L_2 high perceptual contrasts by 12 months of age, but they did not categorize L_2 low perceptual contrasts until 30 months of age. Essentially, children's categorization of high contrasts at middle (L_2) levels of inclusiveness was closer to their ability to categorize at more inclusive (L_1) levels, and their categorization of low contrasts at middle (L_2) levels of inclusiveness was closer to their ability to categorize at less inclusive (L_3) levels. Mandler et al. (1991) presented 18- to 30-month-olds with three degrees of perceptual contrast in a categorization task. They also found that 18-month-olds discriminated high-contrast objects (e.g., dogs vs. fish) but not moderate- or low-contrast objects (e.g., dogs vs. horses or dogs vs. rabbits, respectively) at putatively the same L_2 level of category inclusiveness; 24-month-olds categorized objects with moderate contrast (e.g., dogs vs. rabbits); but only 30-month-olds categorized objects with low contrast (e.g., dogs vs. horses). Rakison and Butterworth (1998) presented evidence suggesting that superordinate categorization in 14- to 18-month-olds is part-based. In categorizing animals and vehicles, children seemed to be responding to categories of "things with legs" versus "things with wheels." Kemler Nelson, Russell, Duke, and Jones (2000) also concluded that function–appearance relations are better understood by young children if the features of functional relevance for category members are easily perceivable, and Trauble and Pauen (2006) learned that 11- to 12-month-olds categorize objects according to their similarity.

Category inclusiveness is not developmentally homogeneous but appears to be differentiated (at least) in terms of degree of perceptual contrast. Certainly low between-category perceptual similarity facilitates categorization. At a minimum, and in answer to the second question raised in the Introduction, the results of our study suggest that ceteris paribus, perceptual contrast plays a role in children's understanding of structural aspects of object categorization. Children's performance, however, is not exclusively driven by perceptual attributes. Twelve-month-olds discriminated objects within L_3 categories (e.g., hardtop from convertible sports cars), yet as a group they showed little evidence of differentially categorizing these sets.

Third, experience and advances in general cognitive abilities may provide access to new individual or shared attributes of objects. Siegler (1996) developed an overlapping waves theory of cognitive development in which children make use of more strategies for problem solving the older they become. In this vein, Oakes and Madole (2003) argued that older children recognize more and different shared attributes of objects and so more facilely shift their attention among attributes. More generally, as people gain more experience, they become capable of finer categorizations. Tanaka and Taylor (1991), who examined categorization at three levels of inclusiveness in adults in a within-subjects design, found that expertise in a domain equated subordinate with basic level categorization.

L_1, L_2, and L_3

Some evidence reviewed earlier supported an $L_2 \rightarrow L_1$ developmental trajectory. The conclusions of this study generally favor $L_1 \rightarrow L_2$, but are not entirely at odds with a less-to-more general trajectory. First, children as a group categorized (high contrast) L_2 and L_1 equivalently. Second, a greater percentage (73.13%) of children actually categorized L_2 (high contrast) than L_1 (68.75%). These observations point to a possible equivalence and developmental primacy of L_1 and $L_{2\ \text{high contrast}}$. Further consideration of the L_1 versus $L_{2\ \text{high contrast}}$ distinction is warranted.

Children's sequentially touching objects from categories with the lowest level of inclusiveness (L_3) did not exceed chance at any age we tested, suggesting that even children 30 months of age fail to make finer between-category L_3 discriminations at least by sequential touching. It is not the case that this group category result is attributable to a failure of within- or between-category discrimination on the part of children or that no children can so categorize. First, several studies demonstrate that much younger infants than we tested can discriminate objects within and between highly specific (low inclusive) categories (such as degrees of smiling intensity in the same face by 5 months in Bornstein & Arterberry, 2003; cats and dogs by 7 months in Quinn, 2004; gender by 9 to 12 months in Leinbach & Fagot, 1993). Second, we showed that children could discriminate objects between the L_3 categories in the same domain. Third, although 30-month-olds as a group did not categorize at the least inclusive level (see Table 2), by individual categorizer classification analyses 40% to 50% of individual 12- to 30-month-olds did (see Table 3). When exactly group performance gives evidence of the ability of children generally to make these finer categorizations cannot be told from these data, but it may well be not until close to their third birthday, given that the type of categorization they need to make is not unlike the categorization needed for low-contrast objects at a more inclusive level (L_2) of categorization that came on line around 30 months.

It is important, however, to take note of claims that younger children make fine categorizations in some domains when tested by other means (e.g., Quinn, 2004), and eventually, of course, children come to make fine categorical distinctions. Analysis of individual data revealed that 40% or more of children categorize at L_3 and therefore must be discriminating subordinate categories. To succeed at them, children must detect subtle attributes that differentiate among category members and ignore equally subtle attributes which are common to members at the same category level, and this challenge appears to present some difficulty. Children might also need to possess an awareness of the importance of differences among objects that transcend their category membership, and they need to allocate more attentional resources to discovering those differences. Even adults devote greater amounts of visual analysis when confronting less inclusive categories than more inclusive ones (Tanaka, Luu, Weisbrod, & Kiefer, 1999). Adults who become experts within a domain come to represent subordinate-level categories as robustly as basic-level categories (K. E. Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Consonant with this perspective, it could also be that, in the interplay of instrumental and perceptual attributes of categories, function has priority in decision making and needs to be suppressed or inhibited for perceptual differentiations to rise to the fore.

Group and Individual Analyses of Categorization

We evaluated children's group categorization (using mean run length), and we also classified individual children as categorizers and noncategorizers. In answer to the third question posed in the Introduction, we found that across all ages and at all levels of category inclusiveness, where the group analyses (see Table 2) showed categorization, 67.5% of individual children on average categorized versus 43.3% of individuals where the group did not categorize (see Table 3). Overall, individual categorizer classifications tended to increase with child age and with category inclusiveness level, converging with the developmental trends found for group comparisons. However, it was also the case that for all ages and levels of category inclusiveness some children in the group categorized competently, even if children as a group did not. Indeed, a minimum of about one third of children categorized in all conditions. As a consequence, we conclude that individual analyses add information to group analyses and that group analyses somewhat mislead with respect to children's potential and accomplishments.

Limitations and Future Directions

In considering our results it is important to bear in mind that these data are based on children's spontaneous touching of objects, which is a performance rather than a competence measure of children's categorization. Task is a critical variable in categorization study, as the process approach shows. Although positive results give evidence that children categorize items, null results are always subject to varying interpretations. Furthermore, the fact that children categorize in the ways we found does not necessarily imply that children's category knowledge is mature, nor does it specify the range of different objects children might encompass within a category. Indeed, categorization findings provide no direct evidence that children touch categorically related objects in succession because they are explicitly aware that the objects represent the same kind of thing. That said, the regular patterns of findings that emerged by age and by category inclusiveness level indicate that some understanding of structural categorization guides children's behavior. In addition, we cannot make definitive statements regarding whether this study assesses existing categories in children or categories that children construct on line (Bornstein & Mash, in press). We would also be remiss in failing to acknowledge that, although we have drawn conclusions regarding developmental trajectory, ours is a cross-sectional study. These findings should be replicated in a longitudinal design (see Pauen, 2002b; Poulin-Dubois, Graham, & Sippola, 1995). In addition, to fully chart the emergence and development of levels of categorization inclusiveness, future research should apparently start at an age younger than 1 year and test children further into their 3rd year.

Our findings excite ideas for other next steps in understanding the development of early categorization. For example, the variation that is exposed by comparing group with individual analyses begs for additional investigations of children in the group who succeed where others fail. Why do some children and not others categorize at a given level? Are individual differences reflective of particular experience? Perhaps parents' labeling objects at certain levels relative to others differentially focuses young children's attention (see Poulin-Dubois et al., 1995). Also, is developmental achievement transitive, so that children who succeed earlier at L_3 do all L_2 and L_1? Furthermore, do children who excel in categorization excel at other related cognitive tasks, such as receptive vocabulary (Ellis & Oakes, 2006)?

Conclusions

Much categorization is ad hoc, and, of course, objects can be categorized in several different ways: A "crayon can be categorized on the basis of color, function, or shape, and the particular way that it is categorized at any given moment depends on the task and on the contrasting items" (Oakes et al., 1997, p. 396). An understanding of categorization is also evidenced by the ability to form categories at different levels of abstraction. A logical and informative goal of research on children's categorization is to focus on process and identify the conditions under which children do and do not categorize one way or another (e.g., Blewitt, 1989, 1994; Greco et al., 1990; Oakes & Madole, 2000). However, the world of categories also consists of universal, structural taxonomies, and understanding which categorical representations children of different ages acknowledge or possess is equally valuable to understanding mental development in childhood as a process orientation (Neisser, 1987). That is, some categories might reflect earlier emerging representations, and we want to know about them just as we want to ask which categories children construct under what conditions. One approach yields a picture of the representational nature of the mind in development, whereas the other approach helps to explain decision making. Both have legitimacy and information value for understanding the development of cognition.

The research presented here contributes to understanding the growth of category representation in young children in several ways. First, in a single study that used a single method, we charted categorization across multiple levels of inclusiveness in multiple domains and ascertained a developmental trajectory among them across the second and into the third year. Spontaneous object categorization appears to begin at more inclusive levels and to move systematically to less inclusive/more differentiated levels. In addition, we provided evidence that perceptual similarity between categories plays a role in categorization. Finally, we found that group and individual analyses of young children's categorization accord well, but individual analyses add unique information about children's categorization ability.

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