Categories, Kinds, and Object Individuation in Infancy

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Psychologists and philosophers have been debating about the nature of categories, kinds, and the role of language in concept representation and concept acquisition for decades if not centuries. When studying the nature of kind representations, much of the literature in cognitive and developmental psychology has focused on the important process of categorization (see the many chapters in this volume). In this chapter, I would like to focus on a less studied aspect of kind representations, namely the process of individuation. I suggest that a theory of kind representations should account for both categorization and individuation.

What is a category and what is a kind? To begin, I will try to lay out a taxonomy to clarify the relationship between the various terms and to pinpoint the focus of this chapter (Figure 1).

Categories (e.g. dog, chair, person, passenger, baby, water, gold, red things, walk, in, things to take to the beach, etc.)

Kinds (e.g., dog, chair, water, gold)

Sortal-Kinds, (e.g.dog, chair, person, baby, passenger)

Substance-Kinds (e.g., water, gold)

Essence Sortals (e.g., dog, chair, person)
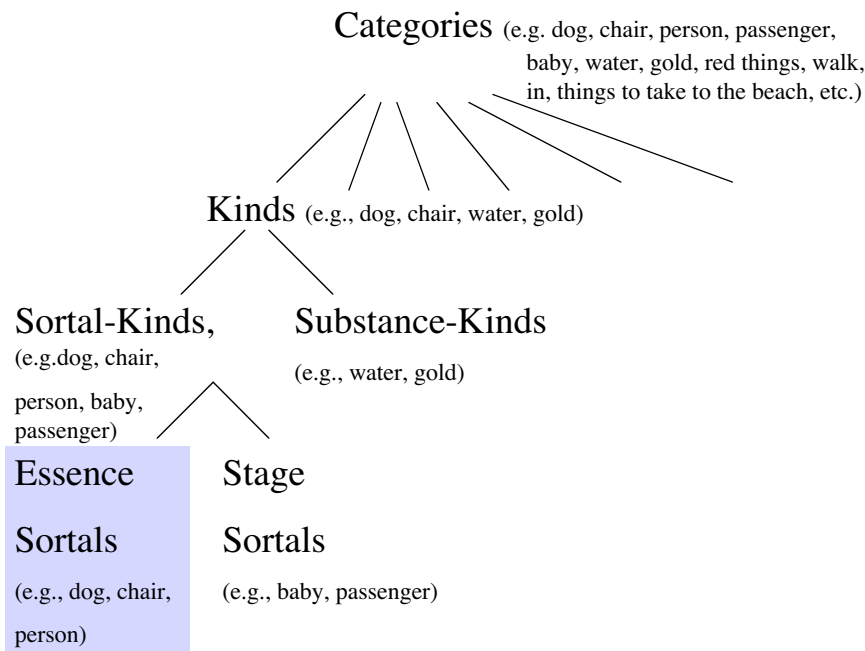
Stage Sortals (e.g., baby, passenger)

Figure 1.

I adopt a very broad construe of categories. Any group of objects that is minimally coherent will be considered a category, e.g., dog, chair, person, passenger, girl, baby, water, gold, red things, things to take to the beach, anything that is bigger than an elephant, all instances of the verb "walk," all instances of the preposition "in," etc. These categories make intuitive sense because all members of each category have some attributes in common, but how coherent or how "tight" these categories are differ dramatically (see Markman, 1989; Millikan, 1996, among others for discussions). For instance, the category dog is intuitively a paradigmatic example of a category, whereas the category red things is a more peripheral example. A subset of categories are kinds. Kinds are categories with rich inductive potential, e.g., dog, chair, person, girl, baby, water, gold. Some kind concepts provide not only the basis for categorization (which all kind concepts do by virtue of being a subset of all categories) but also the basis of individuation.

What is the process of individuation? It is the process for establishing numerically distinct individuals that can be tracked through time and space, e.g., objects, people, events. A subset of all kind concepts, dubbed "sortals" by philosophers of language, provide the criteria for categorization and individuation. To avoid terminological confusion, I will call these concepts "sortal-kinds," which include dog, chair, person, girl, and baby (Figure 1), in contrast with "substance-kinds," which include water, gold, etc. Within sortal-kinds, some individuate and trace the identity of an entity through all of its existence, e.g., dog, person, chair. These are what I will call "essence sortals." Other sortal-kinds only individuate and trace the identity of an entity for part of its existence, e.g., baby, girl, passenger. These I will call "stage sortals."

Why is individuation important and why should a theory of concepts account for both categorization and individuation? Perhaps one way to put the issue simply is that categorization is the process of <u>identification</u>, and individuation is the process of <u>re-identification</u> (Millikan, 1996). Our conceptual system represents categories and these groupings allow us to <u>identify</u> specific instances of categories; our conceptual system also represents kinds and <u>re-identify</u> instances of categories over time. For example, if we identify that a dog (a specific instance of the category <u>dog</u>) walked into a cabin, then a few minutes later, we again identify that a dog (as opposed to a cat) came out of the cabin. We ask ourselves: Was that a single dog going in and coming out, or was that two distinct dogs, one went in and the other came out? That is, re-identification takes place in our conceptual system, most of the time automatically. Re-identification or individuation has consequences in whether our visual system interprets the event as having one or two dogs in the scene, whether the same proper name, Fido, can be applied, and whether we should run faster for our lives should we happen to be afraid of dogs of a particular breed. "Sortal-kinds" are the subset of our categories that provide criteria for both categorization and individuation, that is, identification and re-identification (Millikan, 1996). One reason why the study of individuation is importantly complementary to the study of categorization is because human adults are committed to a world populated with individuals (people, objects, or events) that persist – we may encounter Joe Schmoe on both Monday and Wednesday; we may sit in the same office chair everyday of the week; and we may go to the first and ninth innings of the same baseball game. Most studies of categorization are concerned with how we group and identify instances, leaving open the question whether it was the same object or objects that are categorized each time. The

study of individuation is concerned with precisely the problem of persistence, of objects, people, and events.

Issues of object individuation are relatively new to the study of cognitive and language development, but it has a long history in the study of object perception and attention. Several related phenomena have been studied extensively. For example, the phenomenon of apparent motion has generated a rather large literature of its own and the issue at hand is whether an object is perceived as one and the same, and under what conditions human observers would trade off path of motion information and perceptual property information in tracking objects over time and space. Another example is the "tunnel effect" (e.g., Burke, 1952). Consider the following event: A blue circle goes behind an occluder and a red square comes out the other side (Figure 2). We know that if the spatiotemporal parameters are set within a certain range, adults perceive that the blue circle has turned into a red square. In other words, a single object has persisted through space and time and it has different properties (blue vs. red, circle vs. square) on the two sides of the occluder.
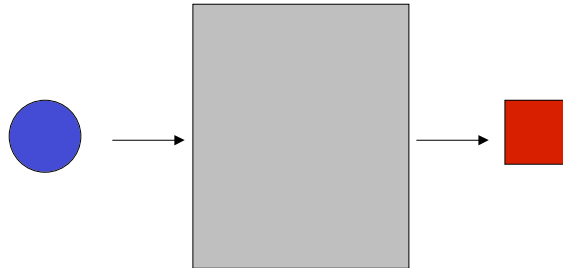
Figure 2.

Now consider a similar event. A dog goes behind an occluder and a cat comes
out the other side (Figure 3). Under conditions identical to the circle/square event, we
would perceive the event as involving two distinct objects, namely a dog and a cat. If the
occluder were removed, we would expect to find the dog behind it. Our representations
of kinds such as dog and cat include a belief that dogs and cats are of different kinds and
have different essences therefore dogs do not turn into cats (e.g., Medin and Ortony,
1989; Gelman, 2003). For adults, these two systems of individuation operate together,
the former being the object-based attention system and the latter being the kind-based
system.

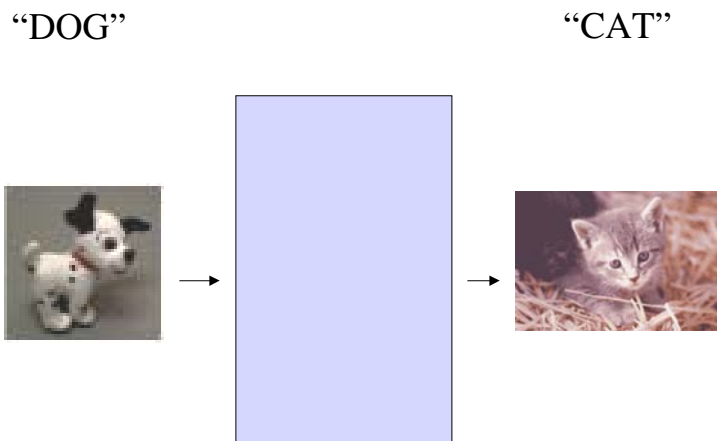"DOG"   "CAT"

Figure 3.

This chapter presents a review of the development of object individuation in

infancy. I will argue that two systems of individuation are present: an early developing

object-based individuation system (by about 4 months of age), and a later developing

kind-based individuation system (starting at around 9-12 months of age). Furthermore, I

will argue that learning labels for object kinds plays an important, perhaps causal, role in

the development of the second, kind-based system of individuation.

What are the initial criteria for object individuation in infancy?

Use of spatiotemporal information for object individuation

In recent years, a number of researchers have shown that even very young infants

employ spatiotemporal criteria in the service of object individuation. Spelke,

Kestenbaum, Simons, and Wein (1995; see also Spelke & Kestenbaum, 1986 and Moore,

Borton, & Darby, 1978) asked whether infants had any criteria for deciding whether an

object is the same one as a previously seen object, using the violation-of-expectancy looking time paradigm. The question about criteria for numerical distinctness is a step beyond object permanence – not only did these researchers ask whether infants represent objects when they are out of sight, but also whether infants have any means for establishing and representing a world that is populated with multiple distinct objects, all of which are permanent. In their studies, 4-month-old infants were seated in front of a puppet stage. Two opaque screens sat on the stage, with some space in between. A rod appeared from behind the left screen and moved to the left side of the stage, then returned behind the left screen. After a short pause, an identical-looking rod appeared from behind the right screen, moved to the right side of the stage, and returned behind the right screen (see Figure 4 for a variant of the procedure with toy objects). The mature understanding of the physical world includes the generalization that objects travel on spatiotemporal continuous paths such that no object can go from point A to point B without traveling through the space in between. Therefore the spatiotemporal information in the event -- no object traveled through the space between the two screens -- informs adults that there must be two distinct objects involved in this event. What about young human infants? Does their mental faculty also possess such understanding of how the physical world works? To answer this question, Spelke et al. (1995) removed the screens on the test trials, revealing to the infants either an event in which a single rod moved back and forth, or an event in which two identical rods moved back and forth. Infants' looking times were recorded. By the logic of this experimental paradigm, if the infants had established a representation of two objects in the event and habituated to it, they should look longer at the single rod event on the test trials. Four-month-old infants

did so. This finding has been replicated with 10-month-old infants using a variant of the procedure and a variety of small objects such as toy trucks, balls, and toy ducks (Xu & Carey, 1996). Furthermore, by 10 months, if the object does travel through the space in between the two screens, infants establish a representation of a single object in the event. That is, not only does spatiotemporal discontinuity lead to a representation of two distinct objects, but also that spatiotemporal continuity leads to a representation of a single, persisting object. Other laboratories have also replicated this basic finding using somewhat different procedures (e.g., Aguiar & Baillargeon, 1999; Wynn, 1992; Simon, Hespos, & Rochat, 1997; among others).
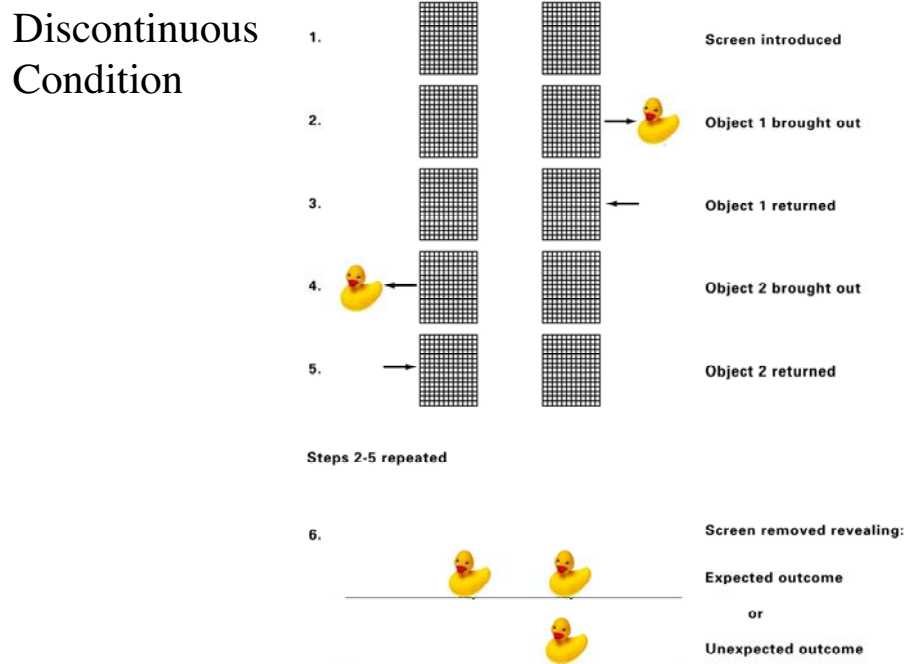

Figure 4.

Thus, even young infants have some criteria for establishing representations of distinct objects. These criteria are spatiotemporal in nature, including generalizations

such as objects travel on spatiotemporally connected paths, two objects cannot occupy

the same space at the same time, and one object cannot be in two places at the same time

(for empirical evidence for the latter two generalizations, see Baillargeon, Spelke, &

Wasserman, 1985; Baillargeon & Graber, 1987; Baillargeon, 1994, 1995; among others).

<u>Use of property information for object individuation</u>

Do infants use other types of information in the service of object individuation?

Adults use at least two other types of information: perceptual property information

(contrasts in color, size, texture, such as a red triangle and a green disc) and object kind

information (membership in different kinds, e.g., a cat seen on the window sill at time 1

and a cup seen on the same window sill at time 2). Wilcox and Baillargeon (1998;

Experiments 7 & 8) first showed that 9-month-old infants were able to use property

information for establishing a representation of two distinct objects. In their study, two

conditions were contrasted. In the box-ball condition, a box (e.g., blue, square/cube-

shaped) moved behind an occluder, then a ball (e.g., red, round) came out the other side.

The occluder was removed to reveal nothing behind it (see Figure 5). In the ball-ball

condition, a ball moved behind an occluder, then a ball came out the other side. The

occluder was then removed to reveal nothing behind it. These researchers reasoned that

if the infants had used the property differences between the box and the ball to establish a

representation of two distinct objects, they should look longer at the ball outcome in the

box-ball condition than in the ball-ball condition. This was indeed what they found.

Inspired by the studies of Wilcox and Baillargeon (1998) and employing a

procedure devised by other researchers (Tinkelpaugh, 1928; LeCompte & Gratch, 1972;

Uller et al., 2000), Xu and Baker (2003) used a manual search methodology to address

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the question whether infants can use perceptual property information for object individuation. Because of the high task demands of a manual search procedure, they tested 10-month-old infants. Infants saw a single object, say a cup, removed from and replaced in the box. On half the trials, the object that the infant retrieved was the same as the object she was shown (no-switch trials). On the other half of trials, the object that the infant retrieved was different from the object she was shown, say a toy duck (switch trials; Figure 5). The retrieved object was then taken away. If the infants had used property information to establish two distinct objects, they should then search more persistently inside the box on the switch trials than on the no-switch trials. This pattern of search was obtained at 10 months. Thus by 10 months of age, infants are able to use perceptual property information for object individuation in both a looking time paradigm and a manual search paradigm.
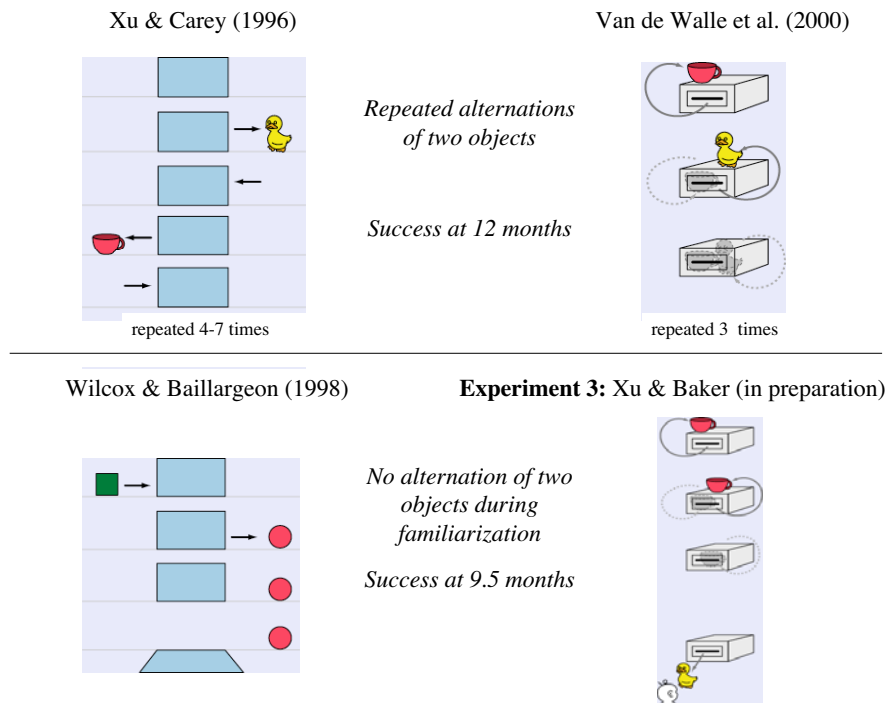

Figure 5.

In sum, studies from various laboratories have shown that infants are able to use spatiotemporal information and perceptual property information for object individuation as early as 4 months of age.

What develops over time? A kind-based individuation system.

Strong spatiotemporal evidence for a single object overrides property information

What about object kind information? Can infants use kind membership as a source of evidence for establishing distinct objects in an event? Xu and Carey (1996) and Wilcox and Baillargeon (1998; Experiments 1 & 2) found that strong spatiotemporal evidence for a single object changing properties overrides property information. In Xu and Carey's experiments, 10- and 12-month-old infants were shown the following event: One screen is put on a puppet stage. A toy duck emerges from behind the screen and returns behind it. After a short pause, a ball emerges from behind the same screen to the other side and returns behind it (Figure 6). The event is repeated a number of time, thus presenting the infants with multiple alternations of the objects: duck, ball, duck, ball, duck, ball, etc. Adults, who understand that ducks and balls are two different kinds of objects and that they do not typically turn into each other behind screens, conclude that there must be two distinct objects. On the test trials, the screen was removed to reveal either the expected outcome of two objects or the unexpected outcome of only one object. If infants are able to use object kind information for object individuation, they should look longer at the unexpected outcome. The results, however, were surprising: 10-month-old infants did not look longer at the unexpected outcome of one object. Their looking time pattern for the one- and two-object outcomes was not different from their

baseline preference, which was measured by showing infants just the two outcomes without familiarization and not surprisingly, the infants looked longer at two objects than one object. In contrast, 12-month-old infants looked longer at the one-object, unexpected outcome, overcoming their baseline preference for two objects. In other words, 10-month-old infants failed to draw the inference that there should be two distinct objects behind the screen, whereas 12-month-old infants succeeded in doing so.

Property/Kind Condition

1. Screen introduced

2. Object 1 brought out

3. Object 1 returned

4. Object 2 brought out

5. Object 2 returned

Steps 2-5 repeated

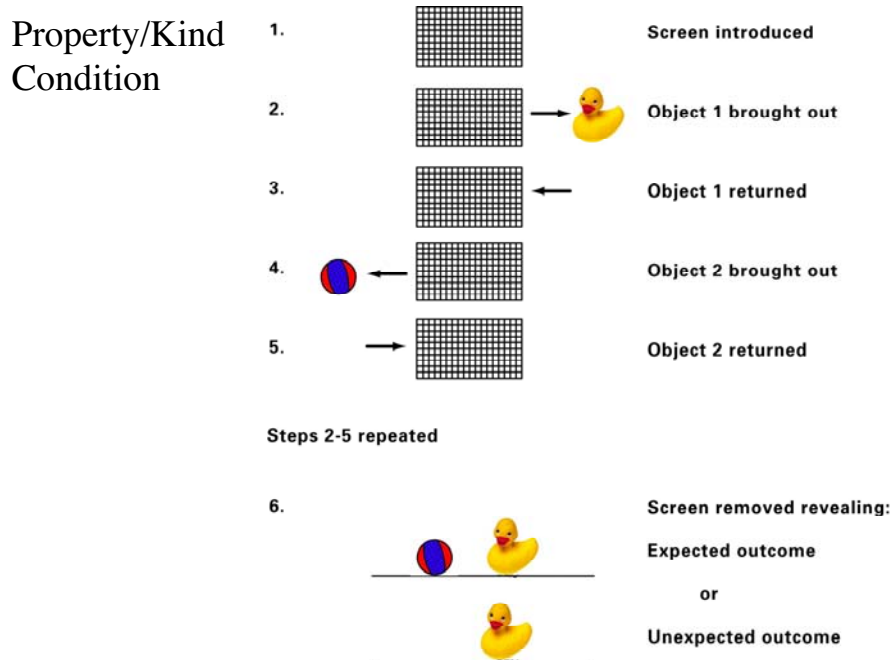6. Screen removed revealing:

Expected outcome

or

Unexpected outcome

Figure 6.

Two critical control conditions established that the method was sensitive. When 10-month-old infants were shown the two objects simultaneously for 2 or 3 seconds at the beginning of the experiment (Figure 7), they looked longer at the unexpected, one-object outcome, overcoming a baseline preference for two objects. Thus when clear

spatiotemporal evidence was provided, these infants were able to establish a

representation of two distinct objects behind the screen.
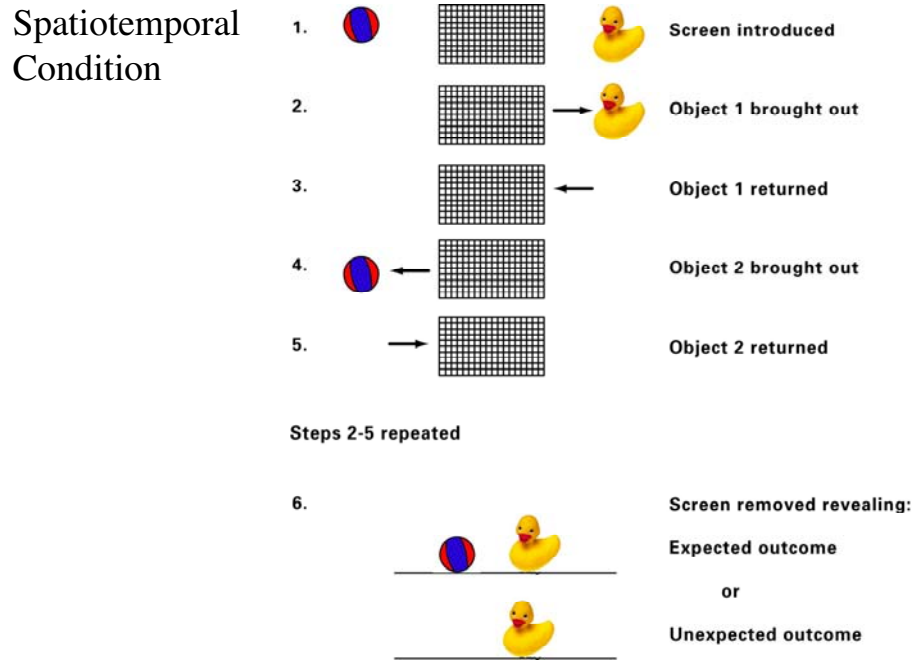
Spatiotemporal Condition

Figure 7.

Furthermore, Xu and Carey (1996) showed that the 10-month-old infants in their

experiments were not blind to the perceptual differences between the two objects.[1]

During familiarization, one group of infants was shown the two objects alternating, e.g.,

duck, ball, duck, ball, and their looking times on these four trials were recorded. A

second group of infants were shown one object repeatedly, e.g., duck, duck, duck, duck,

and their looking times were recorded. The results showed that the looking times

declined less for the first group of infants compared to the second group. That is, it took

the first group of infants longer to habituate than the second group, presumably because

the first group encoded the perceptual property differences between the two objects. This

was an important control condition because it replicated the results of infant

categorization studies in which 3- or 4-month-old infants were shown to be able to

distinguish dogs from cats (e.g., Eimas & Quinn, 1994). These results also allowed us to

better characterize the failure of the 10-month-old infants: their difficulty did not lie in

not being able to encode the perceptual property differences between the objects.

Instead, their failure was due to not being able to take these perceptual property

differences or object kind information into account when computing how many objects

were involved in an event. Wilcox and Baillargeon (1998) replicated this developmental

change using a variant of the procedure.

A third line of convergent evidence comes from Van de Walle, Carey, and Prevor

(2000). In these studies, a manual search procedure was used instead of the violation-of-

expectancy looking time procedure. Ten- and 12-month-old infants were trained to reach

through a spandex slit into a box to retrieve objects; the box was constructed such that the

infants could not see what was inside (Figure 5). Two types of trials were included: one-

object and two-object trials in which individuation must be based on kind contrasts. In a

one-object trial, the experimenter pulled out an object (e.g., a toy telephone), and

replaced it into the box. This was repeated once. In a two-object trial, the experimenter

pulled out an object (e.g., a toy telephone), and replaced it into the box. Then the

experimenter pulled out a second object (e.g., a toy car), and replaced it into the box.

This event was repeated several times; thus as in the Xu and Carey studies, it presented

infants with multiple alternations of the objects. The box was then pushed into the

infant's reach, and patterns of search were measured. After the infant had retrieved one

object from the box, the experimenter surreptitiously removed the second object through

a back slap of the box on the two-object trial. Thus the box was empty on both the one-
and two-object trials. The first object was taken away from the infant; therefore, she was
expected to reach into the box again on both types of trials. The question was: how
persistently would the infant search in the box on the one- and two-object trials when she
found the box empty? If the infant has established a representation of two objects based
on the kind contrasts (e.g., a telephone and a car), she should search more persistently on
the two-object trials than the one-object trials. Twelve-month-old infants, but not 10-
month-old infants, showed this pattern of results.

In addition, Krojgaard (2001) found that even when infants were presented with
objects with personal significance that were brought from home (e.g., the child's own
rattle), 10-month-old infants failed at this task with the same procedure as Xu and Carey
(1996). Similarly, Bonatti, Frot, Zangl, and Mehler (2002) found the same failure with
simple objects (e.g., a blue box vs. a yellow cylinder).

<u>Kind information overrides strong spatiotemporal evidence for a single object</u>

What accounts for the differences in performance between the studies of Wilcox
and Baillargeon (1998; Expt. 7 & 8) and Xu and Baker (2003) on the one hand, and the
studies of Xu and Carey (1996), Wilcox and Baillargeon (1998; Expts. 1 & 2), Krojgaad
(2001), and Bonatti, et al. (2002) on the other? The simplification of the procedure seems
to allow infants to succeed a few months earlier. But why? I suggest that the more
complex procedures provided stronger evidence that the event involved a single object
with different sets of properties at different times. The key difference between the more
complex procedures and the simpler ones was that between multiple alternations of
objects and a single alternation of objects. The former, akin to an apparent motion

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display with a square and a circle alternating several times, induced a stronger perception of a single object. This is characteristic of the object-based attention system. That is, strong spatiotemporal evidence can override perceptual property information (see Xu, 2003, Xu & Baker, 2003 for discussions).

If this is the correct interpretation, what about 12-month-old infants and adults who represented two distinct objects behind the screen even with the complex procedures? One possibility is that the emergence of the second, kind-based system of individuation operates independently of the object-based attention system, and it is this system that allowed for the inference of two objects. In other words, representations of object kinds can override strong spatiotemporal evidence for a single object. However, another possible interpretation is that by 12 months, strong spatiotemporal evidence can no longer override perceptual property information. This second interpretation is at first glance more parsimonious, since it does not posit a new construct, namely the representation of kinds. How can we empirically test these two interpretations?

In one series of experiments, information about object kind -- conveyed by shape -- was compared with information about perceptual properties -- conveyed by color, size, and a combination of color, size, and surface pattern. (Xu, Carey, & Quint, in press). Using the paradigm of Xu and Carey (1996), 12-month-old infants were shown an event in which an object (e.g., a red ball) emerged from behind a screen and returned behind it, followed by an object (e.g., a green ball of the same size and material) that emerged from behind the screen from the other side and returned (Figure 8). On the test trials, the screen was removed. Infants were shown two objects (a red ball and a green ball, the expected outcome) or just a single object (a red ball or a green ball, the unexpected

outcome) and looking times were recorded. We found that 12-month-old infants did not

look longer at the unexpected, one-object outcome, suggesting that they did not use the

color differences to establish a representation of two distinct objects.

**Color
Condition**

1.		Screen introduced
2.	→ ●	Object 1 brought out
3.	←	Object 1 returned
4.	● ←	Object 2 brought out
5.	→	Object 2 returned

Steps 2-5 repeated

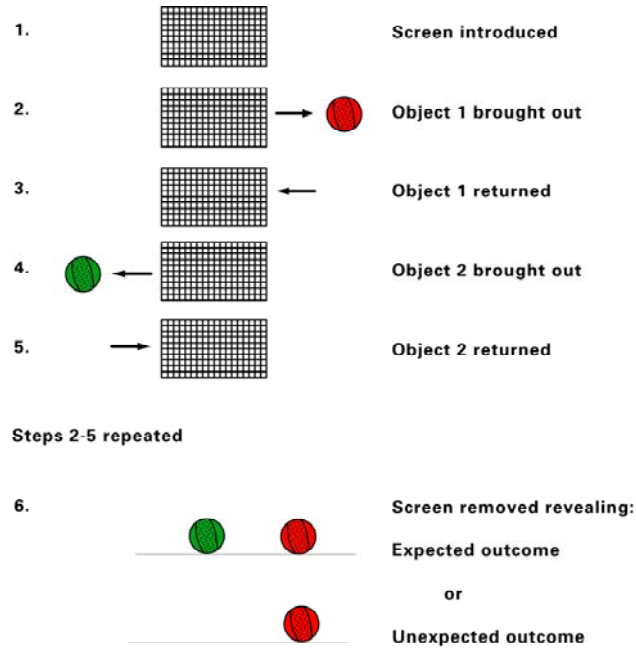|		
6.	● ●	Screen removed revealing:
		Expected outcome
	or	
	●	Unexpected outcome

Figure 8.

Two control conditions were included to ensure that our method was sensitive.

To ensure that the infants encoded the color differences, we compared a group of infants

who saw the two objects alternating (e.g., red ball, green ball, red ball, green ball, etc.)

with another group of infants who saw the same object over and over again (e.g., red ball,

red ball, red ball, etc.). We found that it took the first group longer to habituate, thus

providing evidence that infants at this age were able to encode the color differences in

our experiment. In addition, we tested yet another group of infants for whom

spatiotemporal evidence of two objects was provided, i.e., the two objects, the red ball

and the green ball, were shown <u>simultaneously.</u> In this case, the infants did look longer at the unexpected, one-object outcome on the test trials.

In two other experiments, infants were shown perceptual property differences involving size alone (e.g., a small red ball and a large red ball) or a combination of size, color and surface pattern (e.g., a small green and purple tennis ball glittery and a large glittery red ball), and they failed to establish two distinct objects based on these contrasts, just as in the color experiment. Again, control conditions found that the infants encoded the perceptual property contrasts, but they did not use them for the purpose of object individuation.

In the last experiment of this series, infants were shown two types of shape contrasts (holding color, size, and surface pattern of objects constant) – a within-kind shape contrast (e.g., a sippy cup with two handles and a top vs. a regular cup with one handle) or a cross-kind shape contrast (e.g., a regular cup and a bottle). During familiarization trials, we found that the infants were roughly equally sensitive to both types of shape difference. That is, the rate of habituation was the same in the two conditions. On the test trials, the screen was removed to reveal one or two objects. Only the infants who saw the cross-kind shape contrast looked longer at the unexpected, one-object outcome; the infants who saw the within-kind shape contrast did not look longer at the unexpected, one-object outcome. Together with the results of the first three experiments when property contrasts alone were shown, these findings provide evidence that kind representations (and not just perceptual property representations) underlie the success at 12 months.

A second series of experiments conducted by Bonatti et al. (2002) provided converging evidence for this claim. They found that when an extremely salient and important contrast was given to 10-month-old infants, i.e., a doll head vs. a toy dog head, they succeed in positing two distinct objects with the more complex procedure of Xu and Carey (1996). In contrast, showing a female doll head vs. a male doll head did not lead to a representation of two distinct objects. The authors concluded, and I agree, that it was the kind distinction between human and non-human that explained the success and failure in this case.

In sum, these studies support the claim that kind representations are distinct from perceptual property representations, as they play distinct roles in object individuation at 12 months. These studies also lend support to the conceptual distinction between object-based individuation and kind-based individuation, for this latter system emerges markedly later in development.

Other laboratories have found results consistent with the interpretation that kind representations emerge at the end of the first year. In a categorization task, Waxman and Markow (1995) and Waxman (1999) showed that by 12 to 13 months, infants are sensitive to the distinction between property and kind, as is marked by the linguistic distinction between count nouns (e.g., a dog, a spoon) and adjectives (e.g., it is red; it is square). In these studies, infants were shown a set of objects to play with, one at a time. Upon hearing each of the objects being described by a count noun ("Look, it's a blicket"), infants showed a preference to play with an object of a different kind on the test trial, suggesting that they had extracted kind similarity during familiarization. In contrast, upon hearing each of the objects being described by an adjective ("Look, it's a

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blickish one"), infants showed a preference for an object that differed in some perceptual property (e.g., color or texture) on the test trial, suggesting that they had extracted a perceptual property similarity during familiarization. Since count nouns typically denote kinds whereas adjectives typically denote properties, these results corroborate with the findings of Xu et al. (2003).

Characteristics of the object-based and kind-based systems of individuation

In terms of cognitive architecture, the studies reviewed above provide some initial evidence that two individuation systems are operative: an early-developing object-based system, and a later developing kind-based system. Each system has its own characteristics with respect of the types of information used in establishing distinct objects.

The object-based system of individuation has the following characteristics:

1) Primary criteria for establishing individual objects: spatiotemporal information;

2) Secondary criteria for establishing individual objects: perceptual property information;

3) Strong spatiotemporal information can override perceptual property information.

The kind-based system of individuation has the following characteristics:

1) Primary criteria for establishing individual objects: kind information;

2) Secondary criteria for establishing individual objects: perceptual property information;

3) Perceptual property information is secondary because it is kind-relative (e.g., size contrast may indicate the presence of two chairs, one small and one large, but it does not necessarily indicate the presence of two plants, since a small plant at Time 1 can grow into a large plant at Time 2).[2]

Object individuation studies and infant categorization studies.

The findings of Bonatti et al. (2002), Van de Walle et al. (2000), Wilcox and Baillargeon (1998; Expts. 1 & 2), and Xu and Carey (1996) seem to contradict the findings of many infant categorization studies (e.g., Cohen & Younger, 1983; Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). The following paradigm was often used in infant categorization studies: 3- and 4-month-old infants were familiarized with different pairs of exemplars from a given category, e.g., cat, then they were shown a pair of pictures consisting of a new exemplar from the old category (another cat) and an exemplar from a different category (e.g., a dog). The results showed that infants preferentially looked more at the picture with the exemplar from the new category, suggesting that they had extracted the category similarity during familiarization. These results were sometimes interpreted as evidence that infants represent basic-level kind concepts (e.g., Macnamara, 1986). The Xu and Carey, Wilcox and Baillargeon, and others' findings, however, suggest that perhaps these infant categorization studies show early sensitivity to cat-shape (or cat-properties) and dog-shape (or dog-properties). The infants in the categorization studies did not encode the habituation stimuli as a series of distinct individuals (e.g., a cat, another cat, a third cat that is numerically distinct from the first two) then dishabituate to an object that is numerically distinct from the cats (e.g., a dog). Instead, infants may have discriminated the individual exemplars then extracted the

commonalities among the habituation stimuli as cat-shape or cat-properties and dishabituated to dog-shape or dog-properties (as was also suggested by Quinn, Eimas, and colleagues) . It is only when infants represent distinct individuals, such as cats and dogs, are we warranted to conclude that they represent kind concepts. After all, sortal kinds provide both the basis for categorization and individuation.

Thus there is no contradiction per se between the infant categorization studies and the results of Xu and Carey (1996) and others. The suggestion here (see also Xu, 1997; Xu, 2003; Xu & Carey, 1996) is that the categories revealed by many of the infant categorization studies are perceptual categories. In order to address the issue of kind representations (which are conceptual by definition), more stringent tests may be needed, namely object individuation tasks.[3]

What is the mechanism that underlies the development of the kind-based system of individuation?

I have argued for the existence of two systems of object individuation in adults: the object-based system of individuation and the kind-based system of individuation. Furthermore, I have presented evidence that the object-based system of individuation develops as early as 4 months of age in infancy, whereas the kind-based system of individuation begins to develop towards the end of the first year. As developmental psychologists, we are not only interested in documenting developmental changes, but also the mechanisms that allow changes to happen over time. Thus the key question is: How do these two systems of individuation develop? Some have argued that the object-based system may be largely hard-wired (e.g., Spelke, 1990; Spelke et al., 1992; but see Johnson, 2000, for a different view). What about the second, kind-based system of

individuation? Many have noted that infants begin to comprehend and produce their first words towards the end of the first year, and many of their first words are nouns for object categories. I suggest that it is not a coincidence that along with acquiring their first words, infants also begin to develop a kind-based system of individuation. Some recent studies from my laboratory provide some initial evidence that perhaps language plays a causal role in this process.

Xu (2002) presented 9-month-old infants with the same object individuation task as in Xu and Carey (1996), with the following crucial manipulation: As each object emerged from behind the screen, the infants heard a label for it in infant-directed speech on some of the trials. In the two-word condition, the infants heard two distinct labels in infant-directed speech, "Look, a duck" (when the duck was shown) and "Look, a ball" (when the ball was shown, Figure 9). In the one-word condition, the infants heard a single label applied to both objects (the duck and the ball), "Look, a toy." On some of the familiarization trials, the object was left stationary on the stage and the infant's looking time was recorded. Half of these trials were labeled and half were silent. On the test trials, the screen was removed to reveal either both objects (the duck and the ball; the expected outcome) or one of the two objects (the duck or the ball; the unexpected outcome). If the infants had established a representation of two objects, they should look longer at the unexpected outcome of one object. The results showed that in the two-word condition, but not in the one-word condition, infants looked longer at the unexpected outcome. Thus upon hearing two distinct labels, even 9-month-old infants were able to use the differences in object kind to establish a representation of two distinct objects. Furthermore, this effect was not simply due to hearing some words since the infants

failed the task when a single label was provided. Fineberg (2003) has replicated this basic finding with a different set of objects and words.

Two-word Condition

1. Screen introduced
2. Object 1 brought out
   "Look, A DUCK"
3. Object 1 returned
4. Object 2 brought out
   "Look, A BALL"
5. Object 2 returned

Steps 2-5 repeated

6. Screen removed revealing:
   Expected outcome
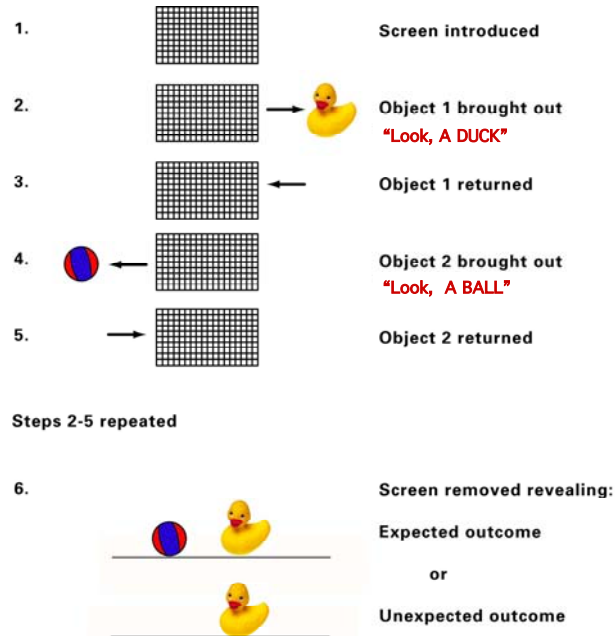   or
   Unexpected outcome

Figure 9.

One may wonder whether the presence of two distinct words heightened the infants' attention to the objects whereas the presence of a single word did not, and whether perhaps more attention led to a fuller encoding of object properties that accounted for the success in the two-word condition. I analyzed the looking time data during familiarization, comparing the silent and the labeled trials. In both the two-word and the one-word conditions, infants' looking times were longer when the objects were labeled than when not labeled. Therefore, the presence of labels did increase the infants' attention to the objects but it increased their attention to the same extent in the two

conditions. It appeared to be the presence of two distinct labels <u>per se</u> that led to the earlier success on this task at 9 months.

An immediate question arises: Are the facilitation effects language specific? Would other types of auditory information help as well? In the next two experiments, instead of using two words, I used two tones or two distinct sounds (e.g., a car alarm sound or a spaceship sound produced by a gadget). As each object emerged from behind the screen, a tone/sound was played (e.g., "Look, [Tone/Sound 1] or "Look, [Tone/Sound 2]"). Under these conditions, 9-month-old infants did not look longer at the one-object, unexpected outcome on the test trials. I also replicated the positive finding of the first experiment, using another pair of familiar objects (a cup and a shoe) as well as a pair of unfamiliar objects labeled with nonsense words (e.g., "a fendle" and "a toma").   In the last experiment of this series, I used two emotional expressions to contrast with words. Emotional expressions provide a particular good contrast with words because both kinds of expressions are intentional and are produced by the human vocal tract. However, only words are symbolic – they stand in for the objects or object categories. Each of us may have our likes and dislikes, e.g., you may say "Ah" when you see broccoli on the dinner table and I may say "Ewy," but we both call the stuff "broccoli." Using the same object individuation task, we presented 9-month-old infants with unfamiliar objects and provided either two distinct words ("a blicket" and "a tupa") or two emotional expressions ("Ah," signaling approval or satisfaction, and "Ewy," signaling dislike or disgust). Infants looked longer at the unexpected outcome of one object on the test trials in the word condition but not in the emotional expression condition. These results

suggest that infants can use distinct labels to help them succeed earlier in an object individuation task, and these facilitation effects may be language specific.

To investigate further how powerful words are in facilitating object individuation in infancy, three lines of investigation are currently underway in my laboratory. In the first series of experiments, we asked whether the presence of labels could override conflicting perceptual information (Xu, 2003). Nine-month-old infants were asked to solve the same object individuation task in which words were pitted against perceptual information. Four conditions were included, crossing two variables: number of objects (one or two unfamiliar objects) and number of labels (one or two nonsense words). That is, infants were shown either a single object emerging from both sides of the screen or two different objects emerging alternately from behind the screen, accompanied by either a single label or two distinct labels. On the test trials, the screen was removed to reveal a single object. The one-word/one-object condition served as a baseline and the looking times of the other conditions were compared with it. The infants in the one-word/two-object condition did not look reliably longer than those infants in the one-word/one-object condition. In contrast, the infants in both the two-word/one-object and the two-word/two-object conditions looked reliably longer than those infants in the one-word/one-object condition. In other words, the number of words appeared to have driven the infants' expectations of how many objects were behind the screen: If two words were used, the infants expected two objects behind the screen; if one word was used, the infants expected one object behind the screen. These findings suggest that words are powerful in guiding object individuation at 9 months, so powerful that they can override perceptual information.

In a second series of experiments, I asked if language is the only mechanism that allows infants to construct object kind representations? Instead of labeling the objects as each of them emerged from behind the screen, each of the two objects made a distinct, internally-generated sound, e.g., one object was a bell mounted vertically on a base, so turning it makes it go "ding;" the other object was a cylinder and when turned upside down, it goes "moo." The sounds were distinct from each other, and the actions for producing the sounds were also distinct from each other. When given the same amount of information as in the two-word conditions, however, 9-month-old infants failed to establish a representation of two objects, i.e., they did not look longer at the unexpected, one-object outcome when the screen was removed on the test trials (Xu, in prep.).

In a third series of experiments, we began to ask whether the act of referring, using labels, would guide the process of establishing object representations in infants (Xu & Cote, in prep.). We employed the same manual search procedure with 12-month-old infants as Van de Walle et al. (2002). Instead of showing the infant objects being pulled out of the box, we simply looked into the box and referred to what's inside, "Look, a fep!" In the two-word trials, two different labels were used; in the one-word trials, the same label was used twice. Then the box was presented to the infant and search behavior was measured. Infants spontaneously reached into the box and they always retrieved one object. Then the critical part of the experiment began. The box was empty and it sat within reach of the infant. The question was whether subsequent search behavior was correlated with the number of labels heard during the demonstration period. An adult would reach in a second time to look for another object if they had heard two distinct labels, but not if they had only heard a single label. Infants behaved similarly: they

reached in more on the two-word trials and when they found the box empty, they searched more persistently on the two-word trials than on the one-word trials. Even without having seen any of the objects, the acts of referring lead the infant to posit objects inside the box, and the number of labels appears to tell the infant the number of distinct objects to be expected inside the box.

These on-going studies provide preliminary evidence that language in the form of labeling is a powerful tool in shaping infants' representations of objects and language may be a particularly efficient way in solving the problem of object individuation for young infants.

What is the role of labeling? Words as "essence placeholders"

What is the mechanism by which labeling could impact on infants' object representations? I suggest that words for object categories are "essence placeholders" (Medin & Ortony, 1989; Gelman, 2003). Hence the term "essence sortals" (see Figure 1). By virtue of being called "a dog," the infant learns that this is a kind, and the word "dog" becomes placeholder for a distinct dog-essence. If an object, seen on a different occasion, is called "a cup," the infants assume that the word refers to a different kind, and it will have a different set of properties from the dogs that are referred to by the word "dog." Although infants cannot learn the concept dog from linguistic input alone, the "dubbing event" may allow the infant to posit a placeholder in his/her conceptual system.

Two other lines of research provide further support for this idea that words are essence placeholders. In a series of categorization studies, Balaban and Waxman (1997) showed that labeling can facilitate categorization in infants as young as 9 months. In their studies, the infants were familiarized with a set of pictures of a given category, say,

rabbits. One group of infants heard a word when shown the picture, e.g., "a rabbit," on some trials. For a second group of infants, a tone accompanied the presentation of the picture on some trials. The results showed that although both words and tones heightened the infants' attention to the objects, it was only in the label condition that the infants categorized the objects. That is, they preferentially looked at an exemplar from a new category (e.g., a pig) compared to an exemplar from the old category (e.g., a new rabbit). These results suggest that in the presence of a label, infants group together the exemplars into a single category more readily than in the absence of a label.

In a series of experiments with 16- to 21-month-old infants, Welder and Graham (2001) found that labeling guides infants' inductive inference, and it sometimes overrides perceptual similarity. In their studies, the experimenter modeled a non-obvious property of an unfamiliar target object, e.g., an object making a rattling sound when shaken, and the infant was given other test objects that were perceptually similar or dissimilar to the target object. In addition, one group of infants heard a label applied to both the target object and the test objects, whereas a second group did not hear a label. The question of interest was whether infants would predict that the test objects would also possess the non-obvious property by reproducing the action, e.g., they should shake the object if they expected it to rattle. The results showed that labeling had a powerful effect on inductive inference, often overriding perceptual similarity.

These results suggest that even early in language development, labeling may exert influence on several aspects of cognition. Infants may expect that words for objects map onto distinct kinds in their environment; words are "essence placeholders." Given this expectation, if each of several objects is labeled as "a rabbit," it provides evidence to the

infant that they belong to the same kind. Similarly, the very fact that one object is called

"a duck" and one object seen on a different occasion is called "a ball" is sufficient

evidence for infants to posit two distinct kinds or essences. According to one of the basic

tenets of psychological essentialism (Medin & Ortony, 1991; Gelman, 2003), essences

determine the surface features and properties of objects. Three consequences follow.

First, if two objects share a label, they should belong to the same kind and their

perceptual property similarities should be analyzed, as in the categorization task. Second,

if two kinds of objects are indeed behind an occluder because two distinct labels are

heard, there must be two distinct tokens of objects, as in the object individuation task.

Third, if two objects share a label, they should have the same non-obvious properties, as

in the inductive inference task. The assumption that words are essence placeholders may

be a mechanism by which infants first establish what <u>kinds of things</u> are in their

environment.

<u>Concluding remarks</u>

I have focused on a less studied aspect of kind representations in this chapter,

namely the process of individuation. I have argued that not all categories are created

equal, some categories are kinds, some kinds are sortal-kinds, and some sortal-kinds are

essence sortals. I have also presented evidence that there is an early developing object-

based system of individuation, and a relatively late developing kind-based system of

individuation. The development of kind-based system is perhaps driven by language

learning. My hope is that this line of inquiry will complement the research on infant

categorization, and we will be able to have a more complete theory of kind

representations that accounts for both categorization and individuation. In this last

section, I will briefly consider the implications of the current research in terms of broader questions in cognitive development and language acquisition.

The conceptual claim that is the foundation of this research is the distinction between kind and property. The basic idea is that representations of kinds define our ontology, and generally speaking, kinds are lexicalized as nouns in natural language. Some of these kinds are sortal-kinds, which provide criteria for individuation and identity and which are lexicalized as count nouns (in languages that make the count/mass distinction). Other kinds are substance-kinds, which are lexicalized as mass nouns, and their role in individuation and identity is a matter of dispute (see e.g., Hirsch, 1982). Whether these kinds are in the head or in the world is not critical, suffice to say that I suspect there is a reasonable correspondence between our representations and what's out there in the world (loosely based on evolutionary arguments). Properties, on the other hand, are a different species. Properties are properties of kinds; they are predicates that correspond to lexical categories such as adjectives and verbs. The studies reviewed above are concerned with properties that can be expressed by adjectival phrases.

A second major claim in this work is a claim about cognitive architecture: an object-based system of individuation and a second, kind-based system of individuation. Each system has its own developmental course and its own characteristics. Each system uses several sources of information and weighs them differently in its operation. The studies reviewed in this paper focus on the interplay between spatiotemporal information, perceptual property information, and kind information.

The third major claim has to do with the role of language in conceptual development. I am inclined to endow the human infant with certain expectations about

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words at the beginning of language acquisition such that in a "dubbing event" (e.g., "That's a dog!"), a word (in this case, "dog") serves as a pointer to a particular sortal-kind in the environment. Via such dubbing events, the infant begin to represent some sortal-kinds, i.e., essence sortals.

The overall view of development I subscribe here is one that has both continuity and discontinuity components. On the one hand, I am sympathetic to the view that human infants are born with a mechanism -- the object-based attention system -- that carves up the world into distinct units. On the other hand, I also suggest that infants' worldview undergoes fundamental changes: They begin with a world populated with objects and substances. By the end of the first year of life, they begin to conceptualize a world populated with sortal-kinds (and perhaps substance-kinds as well). In this new world, objects are thought of not as "qua object" but rather "qua dog" or "qua table." This developmental story makes good sense in terms of learnability, I suggest, because it starts the child on solid ground with the concept of an object (a la Spelke, 1990) and it allows the child to work with these individuated objects and with the help of language, ultimately develop a new ontology of sortal-kinds.

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Acknowledgement

Figure caption

Figure 1. A taxonomy of categories, kinds, kind-sortals, substance sortals, and essence sortals.

Figure 2. Diagram demonstrating the tunnel effect.

Figure 3. Diagram demonstrating the role of kind membership.

Figure 4. Schematic representation of the experimental procedure in Spelke et al. (1995).

Figure 5. Schematic representations of the experimental procedures in Wilcox and Baillargeon (1998), Xu and Baker (2002), Xu and Carey (1996), and Van de Walle et al. (2000).

Figure 6. Schematic representations of the experimental procedure of the property/kind condition of Xu and Carey (1996).

Figure 7. Schematic representations of the experimental procedure of the spatiotemporal condition of Xu and Carey (1996).

Figure 8. Schematic representations of the experimental procedure of the different color condition of Xu et al (2003).

Figure 9. Schematic representations of the two word condition of Xu (2002).

Endnotes

[1] It is important to note that the phenomenon we see here in infants is not the same as the phenomenon of change blindness in adults. The infants in our studies were not blind to the property differences, as was shown in Xu and Carey (1996) and Xu et al. (2003). The difficulty lies in the step beyond detecting perceptual differences in which further computations of numerical distinctness must draw on the perceptual information. In contrast, "change blindness" is a failure in detecting any perceptual differences between two scenes. It does not involve the further computation of establishing numerically distinct objects.

[2] The third characteristics of the kind-based system has not been tested directly with infants. Studies are underway to address this issue.

[3] The study of object segregation, most notably the work of Needham and colleagues, is related to the inquiry in this chapter. The respective roles of spatiotemporal, perceptual property, and kind information have been discussed in detail elsewhere (e.g., Needham & Baillargeon, 2000; Xu, 2003; Xu, Carey, & Welch, 1999). The problem of object segregation is related but not identical to the problem of object individuation (i.e., tracking individual objects over time and space), although some of the same issues arise. I have suggested elsewhere that in the case of object segregation, kind information is very important when perceptual information is ambiguous.