Unresolved Issues in Infant Categorization

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In D. Rakison & L. M. Oakes (Eds.), Early category and concept development. New York: Oxford University Press.

Preparation of this chapter was supported in part by NICHD Grant R01- HD 23397. I wish to thank Cara Cashon for her many helpful comments on this chapter.

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It is a pleasure to be able to contribute to this excellent volume on early categorization and its development. I have had the good fortune to collaborate with some of the authors in the infant section of the volume and I am delighted by the way that they, and others, have built upon the early demonstration studies we and others reported in the 1970's. Today infant categorization is one of the foremost areas within infant cognition, and rightly so.

The ability to categorize is so fundamental that even young infants must possess it to some degree. It allows infants and adults alike to represent groups of objects and events in the world and to act based upon those representations. Infants, as well as adults, must be able to acquire at least some types of categories. Consider what life would be like if they could not. Given that no two experiences are identical, learning from prior experience would be non-existent and anticipating regularities in the world would be impossible. Oakes and Madole (this volume) make a similar point, albeit more conservatively. According to them, “The ability to categorize may be especially important in infancy when an enormous amount of new information is encountered every day. By forming groups of similar objects, infants can effectively reduce the amount of information they must process, learn, and remember…” (pp. xx). But even if we can agree that from the outset young infants possess the ability to categorize, some of the most significant issues still remain. For example, what exactly is the nature of these earliest categories and how do they change with development and experience?

In this chapter, I shall raise a number of issues regarding infant categorization, such as those just mentioned that in my opinion have not yet been resolved. Many of the issues I

will address actually have been around for some time. Several were raised as soon as evidence of infant categorization began to appear. Some, such as the difference between perceptual and conceptual categories, are currently being hotly debated (in this volume, see the chapters by Mandler, Oakes and Madole, Quinn, and Rakison). Other issues, however, such as whether there is a fundamental difference between very young infants' versus older infants' categories, are rarely emphasized. By identifying, or in some cases resurrecting, such issues my intent is to encourage us to consider early categorization in a slightly broader context, to stimulate some new ways of thinking about it, and possibly to generate additional researchable ideas.

Definition of Infant Categorization

I would like to begin with what must be one of the core issues in infant categorization: How does one know when infants have formed a category? Quinn (this volume) provides the usual operational definition of categorization. He writes, "Categorization is assumed to occur when observers respond in an equivalent manner to discriminably different stimuli" (pp. Xx). Cohen and Younger (1983) proposed a similar definition some years earlier. We defined categorization as "a recognized equivalence among stimuli, objects, or events that are discriminably different" (p 197-198). By employing this type of operational definition, both we and Quinn were emphasizing two essential conditions that must be satisfied before one can claim evidence for infant categorization: first that infants respond equivalently to the various exemplars comprising the category, and second that this responding occurs even when the exemplars are highly discriminable from one another.

The earliest report I know of on infant categorization satisfied both of these conditions. I find it interesting that this study is almost never mentioned in the infant categorization literature. Perhaps that is because the author, the late Harry McGurk,

probably did not realize he was inventing a classic paradigm for studying infant categorization. He assumed, as the title of his article, "Infant Discrimination of Orientation" suggests, that he was examining the development of orientation perception. In fact the distinction, or lack thereof, between an infant's responding in terms of an object property, like orientation, versus responding in terms of an actual category is an important issue to which I shall return shortly. But before I do, let us consider McGurk's (1972) design in more detail. It still serves as a model of demonstration studies on infant categorization.

McGurk's experiment is outlined in Figure 1. Infants at 3, 6, 9, and 12 months of age were habituated to one of the three conditions shown in the figure. In Condition A, infants were repeatedly shown the same stimulus, a line with a circle on top. In Condition B, infants were shown that same stimulus but in changing orientations. Infants in Condition C received different stimuli, but in the same orientation. All three groups were tested with the two stimuli on the right side of Figure 1. One was the circle stimulus upside down and the other was a right side up Y stimulus.

What were the results and what do they mean? Very little was found for 3-month-olds. But at 6, 9, and 12 months, infants dishabituated to both test stimuli in Condition A and only dishabituated to the Y-shaped stimulus in Condition B. The results of Condition A indicated that infants at 6, 9, and 12 months can make simple discriminations. They can discriminate the right side up circle stimulus from either the upside down circle stimulus or a right side up Y. The results of Condition B indicated that when the orientation of the circle stimulus varies during habituation, the infants generalize their habituation to the novel upside down circle stimulus. This is an important finding with respect to categorization because is clear from the results of Condition A that they can discriminate that test item, at least from the right side up one.

In Condition C, after being habituated to different stimuli in the same orientation, there was a tendency for the 9- and 12-month olds to dishabituate more to an old stimulus in a new orientation than to a new stimulus in the old orientation. Unfortunately that difference did not reach significance. But the result provides a hint, at least, that 9- and 12-month olds may be able to respond to abstract orientation independent of the stimulus. And if they were responding to orientation, one knows from Condition A that they were doing it despite the fact that they could discriminate the test stimulus in an old orientation from habituation stimuli in that same orientation.

Thus, this study was the first to provide some evidence of infant categorization. It used a prototypic procedure for investigating one version of infant categorization, what some people call "infant perceptual categorization." In Conditions B and C, infants were habituated to a set of changing exemplars and then tested with a new exemplar from the same category versus a member of a different category. The procedure comes close to following the operational definition given earlier. In Condition B, infants responded equivalently to the right side up circle and the upside down circle even though Condition A indicated that the stimuli could be discriminated from one another. In Condition C, infants responded equivalently to the right side up circle and the right side up Y even though Condition A indicated they could be discriminated from one another. So should one conclude that both Condition B and Condition C are instances of perceptual categorization? They both use the same procedure and fit the operational definition to the same degree. But most of us would probably agree that whereas the results of Condition C, which tests for processing abstract orientation, should probably be considered a form of categorization, the results of Condition B should not. Condition B more closely approximates something one would call perceptual constancy; that is, the perception of transformations of the same object (in this case transformations of orientation) as multiple examples of the same object.

Perhaps our operational definition of categorization is inadequate. Perhaps "responding in an equivalent manner to discriminably different stimuli" may be a necessary condition for infant categorization, but not a sufficient condition.

I shall return to this issue shortly, but first let us consider additional evidence. The McGurk (1972) study only provided the suggestion of true categorization since the 9- and 12-month old infants in Condition C did not look significantly longer at the non-exemplar than at the new exemplar from the old category. The study also provided a suggestion that perhaps perceptual constancy occurs earlier than categorization because the 6-, 9-, and 12-month-olds provided clear evidence of orientation constancy, but only the 9- and 12-month olds provided any hint of categorization. Before one makes too much of this study more definitive evidence is needed.

A few years after the McGurk (1972) study appeared, Cohen and Strauss (1977) used essentially the same procedure and a very similar design to investigate infant face perception. The design of their study is shown in Figure 2. Infants at 4, 6, and 8 months of age were given either Condition A, B, or C. Infants in Condition A were habituated to a single color photograph of an adult female face with a particular orientation and expression, e.g. Face 1A. The number (e.g. 1) refers to the particular person and the letter (e.g. A) refers to the combined orientation and expression, for example looking to the upper right with a smile on her face. Infants in Condition B were habituated to different photographs, but they were always the same person with a variety of orientations and expressions. Infants in Condition C were habituated to different females with a variety of orientations and expressions. On the test trials, infants in all three conditions were shown one of the females they had seen before, but for the first time looking straight ahead with a neutral expression, and a new female looking straight ahead with a neutral expression.

The results of Cohen and Strauss (1977) were similar to those found by McGurk (1972). At all three ages infants in Condition A dishabituated to both test stimuli. Thus, they clearly discriminated the habituation face from both the same face with a new orientation and expression, and from a novel face with a new orientation and expression. However, only the 6- and 8-month-olds provided evidence of generalization in Conditions B and only the 8-month-olds provided evidence of generalization in Condition C. In Condition B, infants were habituated to the same face in varying orientations and expressions. Both 6- and 8-month-olds generalized to that same face with a new orientation and expression, but dishabituated to a novel face. In Condition C, infants were habituated to different female faces in a variety of orientations and expressions. Now only the 8 month-olds generalized their habituated response to both test faces.

Thus, as in the McGurk study, the Cohen and Strauss study found evidence of both perceptual constancy and categorization. In Condition B, the oldest infants generalized to the same face but with a novel orientation and expression. One can consider that as evidence for face or person constancy. In Condition C, the oldest infants generalized to a new person's face. One can consider that as evidence for face categorization.

Perceptual Constancy versus Perceptual Categorization

Are perceptual constancy and perceptual categorization the same or different phenomena? Are there any fundamental differences between the two, at least within the realm of infant perception and cognition? These are virtually unexplored questions, although Barbara Younger and I did raise the issue in a chapter several years ago (Younger & Cohen, 1985). Both infant perceptual constancy and infant perceptual categorization seem to fulfill the same operational definition. In both cases infants are responding equivalently to discriminably different stimuli. So, when an infant responds in the same way to her mother when seen in a frontal pose, in profile, or even when only heard from the

next room, is the infant demonstrating "mother constancy" or "mother categorization?" To complicate matters further, perceptual constancies seem to range from basic sensory phenomena, such as brightness constancy, to clearly cognitive phenomena, such as object constancy or mother constancy. Nevertheless adults, at least, do not treat constancy and categorization as the same. Constancy is constrained by the types of permissible transformations an object can take under different conditions. Categories do not appear to have these same constraints. So, for example, if an object appears at a new location, distance, or in a new orientation, one would usually consider it to be the same object. However if the object has a new objective size, color, or shape, one would usually consider it to be a different object, although it may well be a member of the same category. To my knowledge the presence or absence of this distinction between constancy and categorization has not been systematically investigated in infants.

Furthermore there appears to be a developmental progression from the occurrence of perceptual constancy to the occurrence of perceptual categorization. Both McGurk (1972) and Cohen and Strauss (1977) found that perceptual constancy appeared at an earlier age than perceptual categorization. Recall that McGurk found evidence of perceptual constancy at 6 months of age and the possibility of perceptual categorization at 9 months; Cohen and Strauss found evidence of perceptual constancy at 6 months and perceptual categorization at 8 months. This developmental trend was present in both studies. In fact, an examination of the more recent literature reveals the same trend, although occasionally at considerably younger ages. Most studies report evidence of infant categorization by 7 or 10 months, but there are a few reports of categorization as early as 3 months of age (e.g., Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). There also are several reports of perceptual constancy by 3 months (e.g., Bower, T. G. R., 1966; Caron, A. J., Caron, R. F., & Carlson, V. R., 1979; Day, R. H., & McKenzie, B. E., 1981)

and even some demonstrations of it in newborns (Granrud, C. E., 1987; Slater, A., Mattock, A., & Brown, E., 1990; Slater & Morison, 1985).

An interesting fact is that the most successful attempts at finding perceptual constancy by newborns use a procedure that mimics categorization studies. In the Granrud (1987) size constancy experiment, for example, infants were habituated to a ball at different distances and then were shown that ball at a new distance and a different size ball. Newborns in this study dishabituated to the different size ball as if they had formed a category of the ball to which they had been habituated. Slater and Morison (1985) also found evidence of shape constancy in newborns using a design that resembled a category study.

Finally, comparisons between infant perceptual constancy and perceptual categorization are usually confounded in the following sense. Constancy usually refers to equivalence despite variations in some single object property, such as brightness, color, size, or shape. Categorization usually refers to equivalence despite variations in multiple object properties (i.e. variations in the objects themselves). From a constructive, information processing perspective, such as the one I have proposed, (Cohen, 1991; 1998; Cohen & Cashon, 2001) categorization should be more complicated and difficult. According to this information processing perspective the development of infant perception and cognition is basically a bottom-up process. Infants first come to process features or properties of objects before they process the relations among those features that constitute specific objects. They then process the relationships among objects that define simple events, and finally the relationship among simple events that define more complex events or scenarios. Because object properties are the starting point, even if the same underlying representational process is involved in object constancy and the object categorization, I would expect object categorization to appear later than constancy. (By the same argument I

would also expect event categorization to appear later than object categorization.) In any case the distinction, or lack thereof, between infant perceptual constancy and infant perceptual categorization is an issue that deserves further thought and investigation.

Categorical Perception versus Perceptual Categorization

In addition to perceptual constancy, infant categorical perception can also be contrasted with infant perceptual categorization. Infant categorical perception has most often been examined with respect to infants' organization of speech sounds, although it has also been reported with respect to infants' organization of color (Bornstein, Kessen, & Weiskopf, 1976). With respect to speech sounds, as Jusczyk (this volume) points out, the question is whether certain phonetic contrasts, such as /b/ versus /p/ which belong to different phonemic categories, are easily discriminated whereas sounds belonging to the same phonemic category are more poorly discriminated. Research on infant categorical perception of speech also has a long history beginning with the seminal study by Eimas, Siqueland, Jusczyk and Vigorito (1971). In that study, infants as young as one month of age discriminated between /ba/ and /pa/ but were unable to discriminate between different instances of /ba/ or different instances of /pa/. In fact one characteristic of categorical perception is that a sharp boundary exists between two phonemic categories (such as in /b/ versus /p/) and it is easier to discriminate sounds that go across that boundary than sounds that are on the same side of that boundary. My colleagues and I actually plotted out the discriminability function for 7-month-olds who were presented with the medial stop consonants, /aba/ versus /apa/ (Cohen, Diehl, Oakes, & Loehlin, 1992). When the two speech stimuli were on different sides of the boundary infants had little difference discriminating between them. However when the stimuli were on the same side of the boundary (even though the physical difference between remained constant), infants had more difficulty discriminating between the sounds.

So is infant categorical perception an instance of perceptual categorization? The answer appears to be that it usually only meets one half of the definition. Infants' categorical perception, of speech, for example, certainly can be described as responding equivalently to groups of speech sounds. But, it is not at all clear that the sounds comprising a group can be easily discriminated from one another.

In contrast infants also appear to group together speech sounds from quite different speakers. Kuhl (1979; 1983) examined 6-month-old infants' discrimination of two vowel categories, for example /a/ as in "pop" versus /i/ as in "peep". The stimuli within each category varied in pitch contour (interrogative vs. declarative) and in talker identity (male, female, or child). She found that the infants discriminated between the vowel categories, but generalized to instances within a single category, even though those instances were highly discriminable from one another. She concluded that the infants treated discriminably different members of the same vowel category as equivalent, and thus were categorizing speech sounds.

Another interesting case involves infants' reorganization of speech sounds at 10 to 12 months of age. Werker and her colleagues (Werker & Tees, 1984; Werker & LaLonde, 1988) have reported that infants can discriminate a wide variety of phonetic contrasts by 6 or 8 months of age. Some of these contrasts will be phonemic for a certain language (i.e., will produce a meaningful distinction) whereas others will not be phonemic. So, for example, the difference in the initial consonant in the syllables /ba/ and /da/ is phonemic for both English and Hindi. Just switching the initial consonant will change the meaning of a word. But the difference between the dental /da/ and the retroflex /Da/ is phonemic only for Hindi. Both English and Hindi infants can make both distinctions until about 10 months of age. Between 10 and 12 months both groups continue to make the /ba/ - /da/ distinction, but only the Hindi infants make the /da/ - /Da/ distinction. Thus the language environment

appears to make it more difficult for older infants to make a distinction that is not phonemic (or meaningful) in their native language. The question is why that should be the case. One possibility is that the infants actually lose sensitivity to non-native contrasts. Thus, what once was discriminable now no longer is discriminable, or at least is less discriminable. The other possibility is that the infants are not losing sensitivity. Instead they are just responding similarly to equivalent, but discriminable speech sounds. In other words they are forming a true category, and what may begin as an instance of categorical perception becomes an instance of perceptual categorization.

One way to summarize the relationships between perceptual categorization, perceptual constancy, and categorical perception is shown in Figure 3. Each of the three topics can be considered distinct, but each also overlaps to some extent with the other two. Perceptual categorization refers to grouping together multiple examples of different objects (or events) that are easily discriminable from one another. Perceptual constancy refers to grouping together multiple instances of a single object or event. The ease of discriminating among these instances plays a lesser role. Discriminability among exemplars is the crucial issue for categorical perception and whether one considers the different instances (of speech sounds for example) as separate entities (e.g., allophones) or as different examples of the same entity (a phoneme) is of lesser concern. Needless to say an important issue is whether these three topics can best be understood in terms of the same set of underlying processes or whether different sets of processes are responsible for each topic.

Perceptual Categorization versus Conceptual Categorization

No topic is more contentious in the infant categorization literature than the distinction between perceptual categorization and conceptual categorization. According to Mandler (1992, this volume) the two types of categorization are fundamentally different and independent. Perceptual categorization involves the formation of prototypes based

upon perceptual features. It occurs effortlessly and automatically and does not involve abstract representation. Development of this type of category appears to go from the concrete to the abstract. Conceptual categorization, on the other hand, involves deliberation, meaning, and interpretation. Development often seems to go from the abstract to the more concrete. Both types of categories exist from an early age with the only connection between them being a process of "perceptual analysis" by which perceptual information is abstracted into "image schemas", forms of conceptual primitives such as animacy, causality, and containment.

Others, including several authors in this volume (e.g., Oakes & Madole, Quinn, Rakison) argue that such a dual system for categorization is unnecessary. According to this perspective abstract conceptual representation develops out of perceptual representation. This development occurs because of changes in infants' attentional, motor, cognitive, and linguistic abilities. These changes provide new types of information, such as non-perceptual, functional features and contextual constraints that mold and modify early perceptual categories.

Both sides of this debate are well represented in this volume and it is not my intention to restate all the arguments presented by each side. For what it is worth, however, I do tend to side more with the single categorization than the dual categorization approach. First, it seems highly unlikely, and rather unparsimonious, to have two separate categorization systems operating in parallel from early infancy. Second, as mentioned below, considerable evidence now exists to show that these conceptual primitives or "image schemas", from which the conceptual system is supposed to derive "meanings", develop slowly over the first two years of life. They, themselves can best be described in simple perceptual terms at first and only later in more general and abstract terms (See Cohen, Amsel, Redford, & Casasola, 1998) for a description of the development of

causality; Rakison, this volume, for the development of animacy; and both Quinn, this volume, and Casasola and Cohen (In press) for the development of spatial relations such as containment.)

However, the main point I would like to raise in the remainder of this chapter is that this core issue about infants having separate perceptual and conceptual systems versus a single unified system may be impossible to resolve because it is confounded with so many other difficult issues. Some of these related issues are themselves basic to our understanding of infant categorization. Some have been raised in the past and by authors in the present volume. Others are rarely mentioned. Yet the issues must be recognized and resolved before one can achieve a real understanding of the processes underlying infants' acquisition of perceptual and conceptual categories.

Content versus Process

One confounding factor is the distinction between describing the content of infants' categories versus understanding the processes underlying acquisition of those categories. Barbara Younger and I made that distinction back in the early 1980's when we divided infant categorization research into "demonstration" studies versus "process" studies (Younger & Cohen, 1985). Oakes and Madole (this volume) make a similar point when they state, "To fully understand the development of categorization, we must move beyond descriptions of the categories to which infants attend and ask questions about the processes underlying the ability to form these categories" (pp. xx).

Demonstration studies merely provide evidence that infants have formed a category according to the operational definition stated earlier by showing that the infants respond equivalently to discriminably different stimuli. Studies on infants' categorization of stuffed animals versus flowers, dogs versus cats, land animals versus sea animals, or animals versus vehicles are all examples of demonstration studies. Even when these studies go

further to show, for example, that infants attend to an animal's facial features more than its type of body (Quinn & Eimas, 1996) or an object's legs and wheels more than its overall shape (Rakison & Butterworth, 1998) the studies are not providing much information about the processes or mechanisms underlying category acquisition. (One exception would be the series of studies and connectionist simulations of dog versus cat categories reported in this volume by Mareschal). Arguments about whether infants form basic level categories earlier or later than global categories also are often not very informative since they usually do not provide information about how those categories are formed or how the process of category formation changes with development.

The problem is exacerbated when one describes the task in terms of preexisting adult categories rather than infant categories. For example infants may respond differently to sets of toys an adult would represent as "animals" versus "vehicles". But that does not mean that infants have any representations that approximate these adult categories. As Rakison and Butterworth (1998) argued, infants may just be responding to "legs" versus "wheels". But even these terms can become confused with adult categories. Rakison and Butterworth found that infants fail to categorize as different animals with legs and tables with legs. However, it seems highly unlikely that a preverbal infant would form a single category that includes both items.

One of the principle reasons it is so difficult to discover underlying processes from these studies is that they use pre-existing natural categories rather than specially constructed highly controlled, artificial categories. Without being able to manipulate both the objects comprising a category and the features varying among those objects it is difficult, if not impossible, to understand how infants form categories. Both the early research by Strauss (1979) on infant prototype formation and the extensive research by Younger (this volume) on infants' use of correlated attributes provide excellent examples of

process studies. In both cases the investigators examined underlying processes by presenting artificially constructed exemplars to infants. Younger's work in particular has shown not only how important correlations among attributes are in forming categories, but also how important they are for differentiating between categories (Younger, 1985). She also has spelled out in considerable detail age-related changes in the types of information infants will tend to correlate (Younger, this volume). Recently Mareschal and French (2000) have taken process-oriented research to a new level. They have been able to simulate Younger's 1985 results on both category formation and category differentiation using a simple auto-associative connectionist model (see Mareschal's description in this volume).

One impressive aspect of the present volume is the number of authors who are moving past descriptions of infants' categories to propose a set of processes they believe underlie infant categorization. I am glad to see that these authors recognize the importance of correlated information in category formation. They also make serious attempts to explain developmental changes in infant categorization and whether those changes represent modifications in the underlying processes or just the incorporation of new types of information into existing processes. For example, chapters in the present volume by Oakes and Madole, Rakison, and Younger present comprehensive new proposals regarding changes in these underlying processes. Even though the proposals differ, I believe all three are much more complementary rather than conflicting, and they all indicate important directions for future research on infant categorization.

Object Categories versus Event Categories

Most of the discussion on infant categorization relates to how infants categorize objects. Earlier in this chapter I noted the similarity between the categorization of objects and the simpler, perhaps more basic categorization of an object property such as size,

shape, or orientation. This type of categorization, usually called perceptual constancy, tends to appear earlier in infancy than object categorization. One can also look in the opposite direction and consider a more complex type of categorization - the categorization of events. Events involve dynamic change over time and they usually include some type of interaction between or among different objects. As one might expect, infant event categorization tends to appear at a somewhat later age than object categorization. It also is more difficult to define than object categorization.

Consider a simple causal event such as a direct launching in which one object, A, moves across a stage and then hits a second object, B, causing B to move the remaining distance across the stage. One can ask what would constitute a category of that simple causal event? Several studies, during their habituation phases, varied the right-left orientation of the action in the launching event. On some trials infants saw object A enter from the left side of the stage and both objects move from left to right; on other trials they saw object A enter from the right side and the objects move from right to left. This variation in direction of movement did not seem to faze even young infants. They seemed to treat them both as instances of the same event (Oakes & Cohen, 1990). So does that mean the infants had formed an event category and would one call that category "causality"? It seems, at least to me, that the answer would be "no". This grouping of two types of events that simply move in different directions is more analogous to perceptual constancy than to categorization, but at an event level rather than at an object level.

Other studies varied the objects comprising the event. The direction of action, contact and timing remained the same, but a different pair of objects was shown on each trial. (Cohen and Oakes, 1993). This manipulation seriously disrupted infant causal perception and even infants as old as 10 months of age tended to fall back to a simpler, non-causal, type of processing. But assuming that infants at some age can get beyond the

individual objects and can perceive the type of underlying relationship, would they then have formed an event category? Perhaps, but the action has still remained constant. Perhaps the infants had just learned to disregard the particular objects involved in the event. Some might argue that in order for infants to form a true event category they must group together different instances of an event in which the specific action varies but the underlying meaning (e.g. a causal interaction) remains the same. So, for example, one might vary the angle at which object A hit object B and the subsequent direction of movement of object B. Only a subset of these events would actually represent a true causal event. Do infants group together as causal only this subset of events that conform to the laws of mechanics? Suppose they do. Can one then say the infants have acquired a category of causal events? Possibly. Of course, there are many causal events other than direct launchings. Perhaps in order for it to be considered a "real" causal category it must include qualitatively different examples of causal events.

It should be evident from this exercise that as one progresses in this sequence, the notion of causal category is becoming both more general and more abstract. In fact, the sequential order in which these types of categories have been described also probably follows the developmental order in which the categories would be acquired, that is with perceptual constancy appearing first, followed by categorical perception, categorization of objects and finally categorization of events. Such a developmental sequence has implications both for Mandler's notion of an image schema and her distinction between a category and a concept? First, it is clear that development of an image schema, such as one that represents the abstract meaning of causality, is a long, gradual process. Second, this developmental process proceeds from the concrete to the abstract just as in the case of the perceptual categorization of objects. A similar type of progression, based upon the available evidence with infants, can be made for the development of other image schemas

such as "animacy" (Rakison this volume) or "containment" (Casasola and Cohen, in press). Thus it is difficult to understand how conceptual categorization can occur early in infancy when the abstract meanings (i.e., image schemas) required for this type of categorization are not yet available.

Prototypes versus Propositions

Another issue related to the distinction between perceptual versus conceptual categorization is the supposed nature of the underlying representation. If one assumes that a category is essentially a summary representation of a set of exemplars, then a prototype view that includes multiple features, with or without the correlations among those features, would be an appropriate model. This type of model seems to be easiest to apply to object categories. Connectionist models of infant categorization (e.g., Mareschal & French, 2000; Quinn & Johnson, 1997; 2000) seem particularly well suited to constructing this type of representation.

On the other hand certain other categories that at first seem to be abstract conceptual categories, may actually be better described in terms of a set of propositions or rules. Categories that involve relationships between objects can be of this type. They include causal events such as "a direct launching" and spatial relationships such as "above", "below", "inside", "on top of", and "between" (Casasola & Cohen, in press; Quinn, this volume). In fact, these relationships between objects might even be better labeled as concepts rather than categories.

An important, unresolved theoretical question is whether both types of representation are needed or only one type is sufficient. Summary representations seem to work well in determining whether a new object is a member of an existing category. They also provide information about how the representations may be formed in the first place, but they may not be well suited for making inferences or in representing abstract concepts.

(For a contrary view see Mareschal, this volume). Propositional representations may work better in making inferences or in deciding how to classify a totally new object in terms of some abstract representation, but they do not provide much information about how the propositions are initially acquired.

In at least one area of infant categorization the debate rages on. Marcus (1999) showed that 7-month-old infants could learn to categorize a sequence of syllables according to the order in which they appeared, e.g., ABA. Once learned, they also could differentiate that sequence from another sequence, e.g., AAB. Furthermore the infants appeared to learn an abstract rule, given that they were able to generalize the originally learned sequence to an entirely new set of syllables. Marcus also claimed that, in principle, connectionist models can not learn such a rule. Of course Marcus' position has not gone unchallenged. Since Marcus' claim, at least nine different connectionist models have been reported that presumably can learn to approximate such a rule, using processes similar to prototype formation (see Shultz & Bale, in press). Marcus, of course, has argued that these models are insufficient (Marcus, Vijayan, Bandi Rao, & Vishton, 1999). So the issue is still active and unresolved.

Other Issues

The issues raised in this chapter represent only a subset of those that could have been mentioned. For example, one could discuss the pros and cons of a presumed perceptual to conceptual shift, and how the distinction between perceptual and conceptual features is confounded by whether those features are apparent or are hidden and must be inferred. Both Rakison (this volume) and Oakes and Madole (this volume) raise this issue. A related issue is the apparent confounding between perceptual versus conceptual features on the one hand and structural versus functional features on the other.

Another issue, usually not raised in research on infant categorization, concerns the role of habituation (and possibly other procedures) in teaching infants categories. Are infants actually acquiring a category during the habituation phase of the experiment or does the experimental procedure simply indicate categories the infants had previously acquired? With process studies that train infants on artificial categories, the answer seems obvious. The infants are learning the category during the course of the experiment. But what about experiments that use so called "natural" categories? It is usually unclear to what extent prior knowledge influences performance in the habituation task. Connectionist models offer a promising way to investigate this issue as well. Recent models, for example, on infant word learning by Schafer and Mareschal (2001) and on infant causal perception by Chaput and Cohen (2001) explicitly incorporate the effects of prior knowledge in addition to on-line learning during the habituation phase of an actual experiment.

Yet another set of issues relates to the role of language in categorization. Several authors in the present volume, Mandler, Oakes and Madole, and Rakison note that language can have an influence in categorization, but it is not that clear what the underlying mechanisms may be and how those mechanisms change with development. Some experimental findings suggest that the presence of a novel language label facilitates infants' abilities to form categories of objects even when the infants are 12 months of age or younger (e.g., Balaban & Waxman, 1997; Waxman & Markow, 1995). But how does the presence of language work? Does it increase the infants' attentiveness generally, increase it just to salient events, or possibly just to salient objects? (See also Waxman, this volume).

Choi, McDonough, Bowerman, and Mandler (1999) have reported that English and Korean-speaking infants, 18 to 23 months of age, differ markedly in how they group spatial relationships into categories. But the authors differ in their interpretations about the role of language. Mandler (1996) believes infants map linguistic terms to pre-existing spatial

concepts. In contrast Choi and Bowerman (1991) believe that language drives the acquisition of certain concepts. Our own empirical work (Casasola & Cohen, in press) suggests the answer is more complicated. First, we, like Quinn (this volume), found that categorization of spatial concepts proceeds from concrete instances to more general categories. Second, we found that certain categories, like containment, are learned prior to the onset of language, but others like "support" or "tight fit" are not. Certainly much more research is needed to uncover the complex pattern of interactions that exist between category acquisition and language acquisition.

Concluding Comments

It should be evident from the excellent chapters in this volume as well as from the present commentary that infant categorization is an active, productive field and that real progress has been made in a relatively short period of time. We now know that the ability to categorize is present from birth, but the types of categories infants use increase dramatically over the first two years of life. Demonstration studies that seek to discover if infants have learned a particular category are being replaced by more analytic process studies that seek to understand how that category learning takes place. Even the investigation of single processes such as the ability to correlate attributes is being incorporated in more elaborate accounts of category acquisition that involve multiple processes. Furthermore, some of these accounts make a serious attempt to explain developmental changes in categorization and whether those changes include only the acquisition of new features or also qualitatively different ways of forming categories.

It is inevitable that unresolved issues will emerge in a field as active and significant as infant categorization. What is most exciting is that those issues are generating empirical questions both within and beyond the traditional realm of infant categorization research. In this commentary I have identified several of these issues. Some seem obvious and are

currently being debated or researched. Others not have occurred to most investigators in the field.

The field of infant categorization is also being expanded. On the one hand it is being extended to include perceptual phenomena such as perceptual constancy and categorical perception. On the other hand it is being extended to more cognitive phenomena such as categorization of events, relational information, and even rule learning. New approaches, such as connectionist modeling, are beginning to have a significant impact on infant categorization research and these connectionist models are producing predictions that can be tested empirically. Furthermore, the realization that categorization is not an isolated process is leading to a merging of two important areas, the study of early perceptual and cognitive development and the study early language acquisition. As the chapters in this volume indicate, our understanding of infant categorization is undergoing a major change. It is an exciting time to be in the field. Current research on infant categorization and the unresolved issues generated by that research are both contributing to that excitement.

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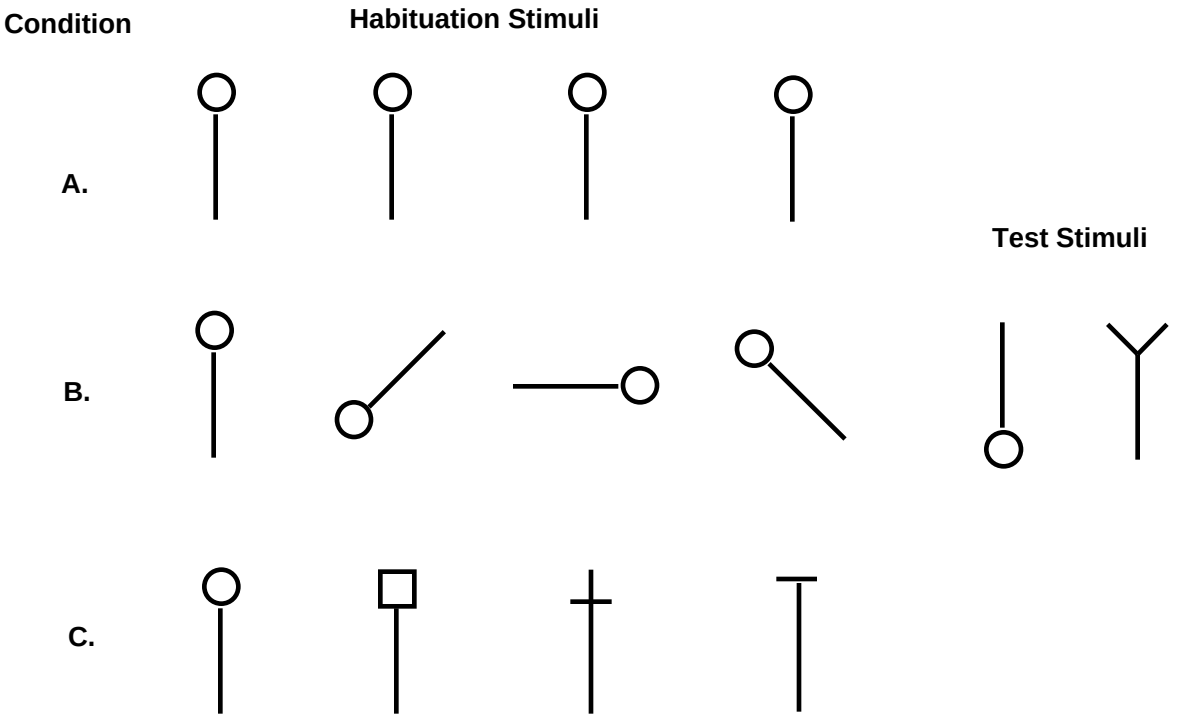
Figure Captions

Figure 1. Design of McGurk (1972) experiment on infant perception of orientation.

Figure 2. Design of Cohen and Strauss (1977) face perception experiment. Notice how similar it is to the McGurk (1972) experiment.

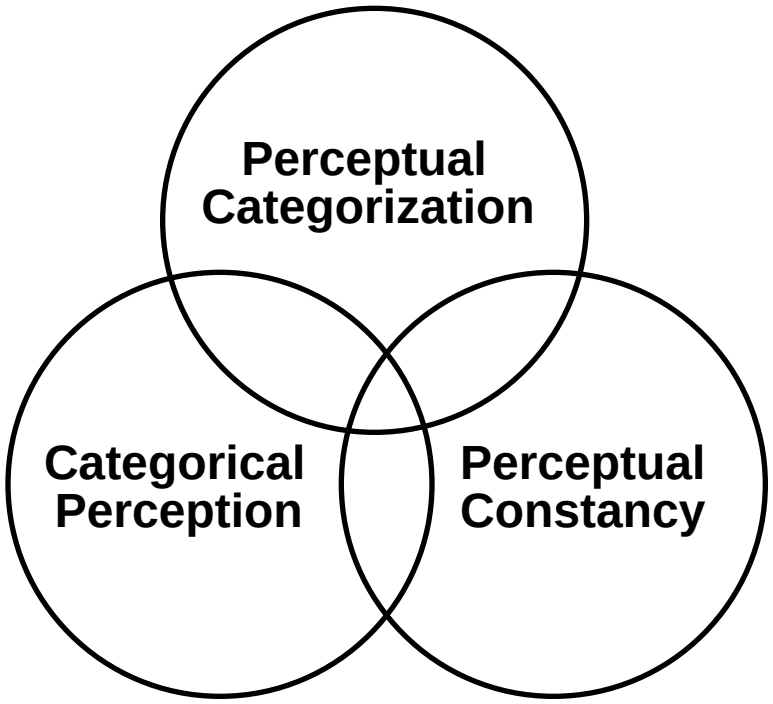
Figure 3. Possible relationships among perceptual categorization, categorical perception, and perceptual constancy.

Design from McGurk (1972)



Design from Cohen and Strauss (1977)

Condition	Habituation Stimuli				Test Stimuli	
A.	Face 1A	Face 1A	Face 1A	Face 1A		
B.	Face 1A	Face 1B	Face 1C	Face 1D	Face 1 •	Fac N
C.	Face 1A	Face 2B	Face 3C	Face 4D		


Perceptual Categorization
Categorical Perception
Perceptual Constancy