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What Does It Look Like and What Can It Do? Category Structure Influences How Infants Categorize

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Despite a large body of research demonstrating the kinds of categories to which infants respond, few studies have directly assessed how infants' categorization unfolds over time. Four experiments used a visual familiarization task to evaluate 10-month-old infants' ($N = 98$) learning of exemplars characterized by commonalities in appearance or function. When learning exemplars with a common function, infants initially responded to the common feature, apparently forming a category, and only learned the individual features with more extensive familiarization. When learning exemplars with a common appearance, infants initially learned the individual features and apparently only formed a category with more extensive familiarization. The results are discussed in terms of models of category learning.

Infants are excellent categorizers. By 4 months infants can form categories based on perceptual properties (Colombo, McCollam, Coldren, Mitchell, & Rash, 1990; Eimas & Quinn, 1994; Oakes, Coppage, & Dingel, 1997; Quinn & Eimas, 1996; Quinn, Eimas, & Rosenkrantz, 1993; Rakison & Butterworth, 1998), and 6- to 10-month-old infants can form categories of abstract properties such as spatial relations (Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003). Moreover, infants flexibly form different categories depending on the particular task or stimuli (Colombo et al., 1990; Mareschal, Quinn, & French, 2002; Oakes et al., 1997) and when presented with novel categories they form prototypes (Younger, 1985) and learn the correlations among attributes that define those categories (Younger & Cohen, 1986). Clearly, therefore, we have learned much about the kinds of categories to which infants respond and the kinds of categorical representations they form. What we do not yet fully understand is how infants' categorization unfolds over time. That is, how do infants initially represent items from within a category and how does that representation change as they have more experience with the category? Answering these questions was the goal of the present investigation.

The adult categorization literature suggests that categories may be represented by exemplars or prototypes, that is, either by remembering individual examples of the category or by representing a prototype of the category. For example, the category *dog* may be represented by storing each of the dogs one has encountered or by creating a summary representation that portrays the entire category (Murphy, 2002). Evidence suggests that infants form both categories organized as collections of individual exemplars (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Younger, 1993) and categories organized around prototypes (e.g., Bomba & Siqueland, 1983; Strauss, 1979; Younger, 1985). For example, Quinn and Eimas (1998) familiarized 3- to 4-month-old infants with 12 exemplars of either cats or humans. At test, infants familiarized with cats looked longer to a novel out-of-category stimulus (a human) than at a novel item from within the familiar category (a cat) but looked equally at novel and familiar items from within the category. Infants familiarized with cats, therefore, apparently had formed a summary representation of the category to which they were familiarized and did not represent the individual items. Infants familiarized with humans, in contrast, looker longer to a item from within the category than to one of the familiar items but did not look longer at a novel out-of-category item (a cat) than a novel item from within the category (a human). These infants, therefore,

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apparently represented the individual exemplars to which they had been familiarized.

Furthermore, the two types of categories—exemplar based and prototype based—are not mutually exclusive. In fact, two recent theories suggest that the difference between exemplar- and prototype-based categories is due in part to the familiarity and experience one has with the category (Quinn, 2002; Smith & Minda, 1998). This suggests that understanding when infants form exemplar- and prototype-based categories will provide insight into how infants' categories unfold over time, in general.

Recent work by Smith and Minda (1998) on adults' learning of categories suggests a summary representation (or prototype) to exemplar shift—at least when categories are relatively easy to learn. Smith and Minda argued that adults form a prototype when they are first learning items in a category task and that only after extensive training do they remember the individual exemplars. Exemplar-based approaches are dominant when categories are sparse and difficult: Participants first learn the individual items and only with additional exposure do they form a summary representation. In other words, the particular processes involved in adults' category learning depend both on aspects of the stimuli and on the context in which the stimuli are presented. If infants and adults use the same processes in forming categories, infants also should form a summary representation early in learning and remember the individual exemplars later in learning if categories are relatively easy to learn, but they should learn the exemplars first if categories are more difficult to learn.

Quinn (2002) proposed a three-stage model of how infants' category representations change with increasing familiarity with category instances. First, when presented with a small number of novel items from a completely unfamiliar category, infants remember individual exemplars (Quinn, 1987). Later, after exposure to additional exemplars, infants cluster those exemplars to form a summary representation, or prototype. Finally, with even more experience with the category, infants may form a category attractor that consists of a summary representation as well as stored representations of individual exemplars. Therefore, in laboratory tasks when the items and categories are novel, infants should first learn the exemplars and only later form a summary representation of those items. When presented with items from familiar categories, infants should form a prototype if those categories are less familiar and represent the individual items if the categories are very familiar. Indeed, in support of the latter two stages, Quinn and colleagues (Quinn, 2004; Quinn et al., 2002) found that infants familiarized with novel instances of the relatively familiar categories *humans* or *female faces* (all infants had female primary caregivers) seemed to remember the individual exemplars but did not respond to the distinction between humans and nonhuman animals or between male and female faces. Infants familiarized with novel instances of the less familiar category *nonhuman animals* or *male faces*, in contrast, did not remember the individual exemplars but did respond to the distinction between humans and nonhuman animals or between male and female faces.

The present investigation addressed the earliest stage of learning a completely novel set of stimuli. In particular, we evaluated two factors that may influence whether infants first form summary representation or first store individual exemplars: the amount of familiarity with the category exemplars and the particular features on which category formation can be based. One way to explore the role of familiarity in infants' category learning is to probe categorization at different points in learning. Previous research has shown that infants' categorization is influenced by how fully habituated they are (Reznick & Kagan, 1983). In the present set of experiments, we sought to evaluate changes in infants' categorization over time by assessing their responding to novel items after varying amounts of familiarization. We therefore could determine under what conditions infants would form a summary representation before learning the individual items versus learning the individual exemplars and later learning what those exemplars have in common.

In addition, we expected that the pattern of category formation would vary with the features of the stimuli on which categorization could be based. In the present set of experiments, we compared infants' categorization of items that shared a common static feature, or appearance (roughly, what objects look like), with their categorization of items that shared a common dynamic, transient feature, or function (roughly, actions that can be performed on objects; see Nelson, 1973, 1974, 1979; Oakes & Madole, 2000, 2003). In these experiments, an experimenter performed actions on objects, which resulted in those objects apparently producing sounds. In this context, therefore, function is this product of the action producing a sound—analogous to shaking a rattle or ringing a bell. We recognize that function can be defined in a number of ways (see Nelson, 1973, for a discussion) and that the dimension we manipulated may only partly capture what is typically meant by function. However, for ease of discussion we have chosen to use the term *function* to refer to the dynamic, intermittent feature, and *appearance* to the static, constantly available feature.

There is reason to believe that function as we have defined it is more difficult to process and learn than appearance. Unlike appearance, which is constantly available, function is only available when it is demonstrated. In addition, unlike appearance, function can only be determined by integrating information over space and time—in the stimuli used here, the function is revealed dynamically over several seconds as a hand reaches for and acts on an object, and a resulting sound is heard. The ability to integrate information over space and time has been shown to be a relatively late-developing skill, typically emerging after 10 months (Arterberry, 1993; Arterberry, Craton, & Yonas, 1993; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). If function is indeed more difficult to process than appearance, it should be harder for infants to learn categories based on commonalities in function, and when exposed to function-based categories infants should first learn the individual exemplars and only later form a summary representation. Because appearance-based categories are easier to learn, when exposed to appearance-based categories infants should first form a summary representation and only later learn the individual exemplars.

However, evidence from other studies suggests that dynamic features may be more salient than static, perceptual features (Mandler, 2000a, 2000b; Nelson, 1973, 1974; Robinson & Sloutsky, 2004). Nelson (1973) argued that because change is more salient than stability, things that change over time are easier for infants to learn. Indeed, from a few hours after birth, infants are more interested in and attentive to dynamic stimuli than to static stimuli (Slater, 1989; Slater, Morison, Town, & Rose, 1985). When habituated to bimodal stimuli, infants selectively attend to and remember the dynamic, intermittent auditory component and not the static, constantly available visual component (Lewkowicz, 1988a, 1988b; Robinson & Sloutsky, 2004). Children's early vocabularies consist of many words to refer to people, animals, and objects that move, rather than to objects (such as walls) that do not change (Nelson, 1974). Therefore, infants may more easily form categories based on commonalities in function than categories based on commonalties in appearance. In this case, infants familiarized with objects that share a common function should first form a summary representation and infants familiarized with objects that share a common appearance should first remember individual exemplars. In summary, we expected that infants' learning of function-based and appearance-based categories would show different patterns, but we had no a priori predictions about which pattern would characterize learning of each type of category.

In the present experiments we extended previous findings to provide a deeper understanding of how infants form categories. Specifically, in three experiments we familiarized 10-month-old infants with items from categories based on a common appearance or a common function and manipulated across experiments when during learning we probed their representation. If infants are representing categories based on individual exemplars, they should discriminate between a novel instance of the category and previously seen instances, and thus dishabituate to a novel exemplar from the category. In contrast, if infants are representing categories based on a summary representation, they should discriminate between the category as a whole and other categories, and thus dishabituate to a novel exemplar from a different category. This design allowed us to establish whether infants initially formed exemplar-based categories or formed summary representations of the objects and whether the types of categories infants formed varied as a function of whether they were familiarized with objects that shared static perceptual features (appearance) or dynamic features (function). In a fourth experiment we determined whether infants encode and remember both appearance and function in individual objects, and whether attention to the two types of features varies as a function of when infants' representations are probed during learning. Because the processes that govern discrimination are presumably different from those that govern categorization (Quinn & Eimas, 1998), we would not expect to find the same asymmetry in attention to the two types of features in a discrimination task that we would find in a categorization task. By assessing infants' categorization and discrimination of these stimuli, we can establish that any differences in the salience of one type of feature are specific to the process of forming categories. Moreover, if we observe that infants fail to dishabituate to a novel object from a familiar category, the results of the discrimination task will establish whether this failure is due to infants' inability to discriminate among items from within the category.

Experiment 1

The goal of Experiment 1 was to assess infants' attention to appearance and function when familiarized with four objects that shared either a common function or a common appearance. Half of the infants were presented with objects that had a common appearance and half of the infants were presented with objects that had a common function.

Method

Participants

Participants were 24 healthy, full-term, 10-month-old infants with no history of birth complications or vision problems ($M = 43.93$ weeks, $SD = 1.15$ weeks, range = 42.00 weeks to 46.14 weeks; 10 girls, 14 boys). Nine additional infants were tested but their data were not included in the final analyses because of fussiness ($n = 7$) or experimenter error ($n = 2$). Infants were predominately from White middle-class families. All of the mothers had graduated from high school, and 64.58% had completed at least a bachelor's degree. In each of the experiments reported, infants' names were obtained from county birth records. When the infant approached 10 months, parents were contacted by letter and a follow-up phone call to schedule an appointment. Parents were reimbursed for parking and infants received a small toy for their participation. Infants only participated in one of the experiments reported.

Stimuli

The stimuli were 25 digitized movies of videotaped events. Each movie clip was approximately 7 s in duration and was looped to replay continuously for 30 s or until the infant looked away. In each movie clip, an object with one of five appearances was manipulated. The objects themselves were approximately 10 cm when presented on a 17-in. computer monitor, and subtended 14.04 degrees visual angle at a viewing distance of 40 cm. Each clip began and ended with the object stationary in the middle of the screen. Each clip included the following sequence: The object was stationary for approximately 1 s; a hand appeared from the right and reached for and grabbed the object; an action was performed on the object (shaking, squeezing, rolling from side to side, pulling a part of the object, or inverting the object) for approximately 5 s; and the hand withdrew, leaving the object stationary for approximately 1 s. Although there was some variation in this sequence across the 25 stimulus events, in general for each 7-s cycle the object was stationary for approximately 2 s and the action was performed for approximately 5 s. Each action was accompanied by a sound: Shaking was accompanied by a rattle, squeezing was accompanied by a squeak, rolling was accompanied by a series of clicks, pulling was accompanied by a whistle, and inverting was accompanied by a cow-like moo. The manipulation on the object appeared to cause the object to produce the sound. For example, in one movie the hand came in and grasped the "hair" of the purple object between the thumb and index finger so that the whole object remained visible and lifted the hair, which was connected to the "head" by a narrow tube (see Figure 1). As the hair moved up and down a whistle sound played, as if pulling the hair caused the object to produce the sound. When this action and the other four actions were performed, care was taken to ensure that the hand did not occlude the object. Therefore, the entire object could be viewed during this part of the sequence. Likewise, inverted, shaken, and squeezed objects were held from behind with only the thumb and finger tips visible on the sides of the objects, and rolled and pulled objects were pinched between the thumb and index finger as in the preceding example. The five appearances and five functions were crossed to produce 25 movies depicting 25 objects. These 25 objects could be grouped into five categories based on appearance or into five other categories based on function (see Table 1).

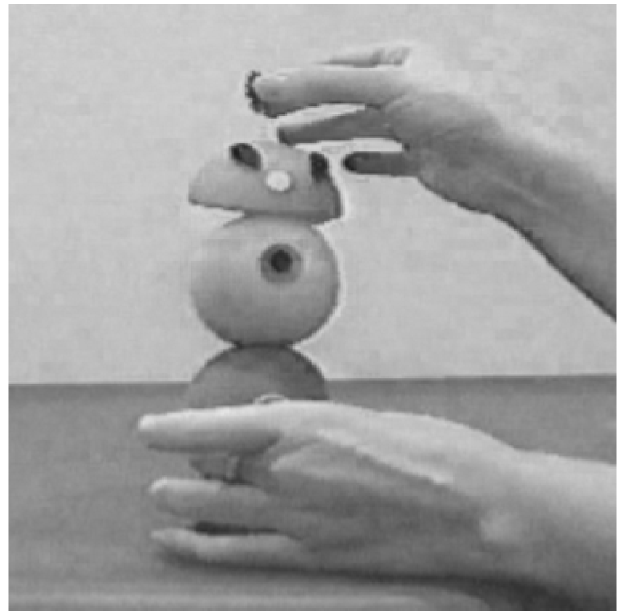
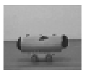
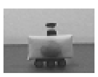


Figure 1. Frame from one of the stimulus events used in all experiments.

One additional clip was used on the pretest trials and completely novel test trials. This clip was of a black-and-white border collie running from left to right across a gray background and lasted approxi-

Table 1
Combinations of Appearances and Functions Used for All Experiments

	Function				
Appearance	Roll/click	Invert/moo	Squeeze/squeak	Shake/rattle	Pull/whistle
 Multicolored	Multi – roll	Multi – invert	Multi – squeeze	Multi – shake	Multi – pull
 Pink	Pink – roll	Pink – invert	Pink – squeeze	Pink – shake	Pink – pull
 Purple	Purple – roll	Purple – invert	Purple – squeeze	Purple – shake	Purple – pull
 Pyramid	Pyramid – roll	Pyramid – invert	Pyramid – squeeze	Pyramid – shake	Pyramid – pull
 Yellow	Yellow – roll	Yellow – invert	Yellow – squeeze	Yellow – shake	Yellow – pull

mately 4 s. Similar to the other clips, the collie clip looped to replay for up to 30 s or until the infant looked away. Between trials a green circle appeared on the screen and loomed at approximately 1 Hz while a beeping sound played to reorient the infant to the screen.

Apparatus

The experiment was conducted in adjacent experimental and control rooms. A Macintosh G4 computer, located in the control room, was used to present the stimuli on a 17-in. (43.2-cm) ViewSonic monitor, located in the experimental room. The computer was also used to record infants' looking time to each stimulus presentation and determine when the habituation criterion had been met (see the following).

Design

Infants were randomly assigned to one of two familiarization conditions: appearance constant or function constant. In each condition, infants were familiarized with four different stimulus events. In the appearance constant condition, each event revealed an object with the same appearance being manipulated in one of four ways. For example, an infant might have seen four events involving objects with the purple appearance, but the object in one event was inverted and made a mooing sound, the object in another event was rolled and clicked, the object in a third event was squeezed and squeaked, and part of the object in a fourth event was pulled and produced a whistling sound. In the function constant condition, each event revealed an object with a different appearance being manipulated in the same way. For example, an infant might have seen four events in which an object was rolled and it clicked, but the object was purple in one event, pink in another event, yellow in a third event, and multicolored in the fourth event. Thus, in both conditions infants were familiarized with four different objects: In the appearance constant condition, the objects shared a common appearance; in the function constant condition the objects shared a common function.

It may be argued that in each condition infants were actually familiarized with a single object that varied in one feature: In the appearance constant condition the stimuli may be construed as one object that had four possible functions, and in the function constant condition the stimuli may be construed as one object that had four possible appearances. From an adult perspective, this alternative construal seems more plausible for the appearance constant condition than for the function constant condition—real-world objects exhibit multiple functions more often than they change appearances. However, it is not clear that infants view appearance as an inherently more stable feature than dynamic features such as function. Based on evidence that 10-month-old infants familiarized to a yellow duck and white ball appearing alternately from behind an occluder responded at test as if they had seen a single object that changed in appearance, Xu and Carey (1996, 2000) argued that infants do not represent appearance properties as features of objects. Infants in the function constant condition of the present experiment, therefore, may actually experience one object with multiple appearances, and infants in the appearance constant condition may experience several objects that differ in function.

A related issue is how the processes of recognizing object constancy and categorization of discriminably different objects are related. These two processes may be fundamentally similar (Cohen, 2003; although see Quinn, Slater, Brown, & Hayes, 2001, for a different perspective): Both involve recognizing commonalities across experiences. Indeed, the evidence for object constancy and object categorization is the same. In both cases, infants habituate to a varying set of stimuli and dishabituate to a dissimilar item. This discussion makes it clear that it may be impossible to differentiate between infants' perceiving a set of items as multiple views, or encounters, with a single object (e.g., object constancy) or multiple examples of a group (e.g., object categorization). However, it may be easier for infants to perceive familiarization as multiple encounters with the same object (either with different functions or different appearances demonstrated on each encounter) than multiple single encounters to several related, but different, objects. In this case, we may observe that infants habituate more easily in one condition because infants are engaging in object constancy rather than in object categorization.

Procedure

Infants were tested in a quiet experimental room. Infants sat on their parents laps about .40 m from a computer monitor. During the session, parents wore opaque glasses and listened to music from a portable cassette player with headphones to minimize bias. A black curtain hung from the ceiling to the floor of the testing room, with openings cut out to reveal only the computer monitor and external speaker. Another opening in the curtain revealed the lens of a camera that was centered below the computer screen (see Figure 2).

A trained observer sat in the next room and recorded the infant's looking time on each trial using a program developed for the Macintosh (Cohen, Atkinson, & Chaput, 2000). The observer was unaware of the infant's condition, the stimulus presented on each trial, or the time when the habituation phase ended and the test phase began. The attention getter

Figure 2. The apparatus used in all experiments.

played at the start of each trial. The observer pressed a key when she judged that the infant was attending to the looming circle. This key press simultaneously stopped the attention getter and initiated the movie clip. The observer recorded the duration of infants' fixation to the display by pressing and holding another key. If an infant did not look at the screen during the 1st s of the trial, the trial was repeated. The attention getter started immediately after a trial ended, and the observer once again waited for the infant to fixate on the attention getter before initiating the next trial. This sequence continued until the infant finished the test phase.

In addition to the online coding of looking times, at least 20% of each sample was recoded offline from the videotapes of the sessions by a different trained observer. The mean interobserver correlation for the duration of looking on each trial (in seconds) was high ($r \geq .99$ for each sample), and the mean absolute difference between observers was low ($M \leq .53$ s for each sample). Only the original online data are reported here.

The first two trials were the pretest phase, during which infants received two trials with the completely novel stimulus. Immediately following this phase was the habituation phase, which continued until infants' looking time habituated or until 24 trials had been completed. Infants received up to six blocks of four trials each. The order of the stimuli within each block was random, with the constraint that the same object was never displayed on two consecutive trials (e.g., the same stimulus could not be presented on the last trial of Block 1 and on the first trial of Block 2). In this experiment, habituation was determined by considering the duration of looking in nonoverlapping blocks; thus, Trials 1 to 4 constituted Block 1, Trials 5 to 8 constituted Block 2, and so on. Habituation was determined by comparing the duration of infants' looking in the first block with the duration of looking on each successive block. Once their looking had decreased to 50% of the amount of looking exhibited in the first block, infants were determined to have habituated. Using this criterion, 62.5% of infants in this experiment habituated, 50% in the appearance constant condition and 75% in the function constant condition. The analyses include data from all infants, both habituators and nonhabituators, because, as described later, there was no effect of habituation status on responding during test.

Immediately following the habituation phase, the test phase began. Each infant received four test trials. The first test was a familiar test, in which one of the four items presented during familiarization was presented. Next, infants received a novel appearance/familiar function test and a familiar appearance/novel function test; the order of these two trials was counterbalanced across infants. The objects that served as the stimulus on the familiar, novel appearance, and novel function test trials were counterbalanced across infants in each condition. That is, each stimulus event was used during the habituation phase for some infants and during the test phase for others. For example, in each condition the purple pull event was used during the habituation for some infants as well as on the novel appearance (purple) and novel function (pull) trials for other infants. Infants' responding to the novel appearance and novel function tests provides insight into what they learned during familiarization. Specifically, three patterns may be revealed: infants may respond to (a) the common feature and dishabituate to any item that does not have that common feature, (b) the individual features and dishabituate to any item that has a new unique feature, or (c) both types of features and dishabituate to any novel item.

Finally, each infant was presented with the completely novel trial as the fourth test trial. Regardless of their responding to the other novel items, we expected that all infants would increase their looking to this item.

Results

Initial analyses revealed there were no systematic effects of infant gender on responding during the test in any of the experiments reported here. Thus, all of the reported analyses were collapsed across this variable. In this and all experiments reported here, the familiarization and test phases were analyzed separately.

Familiarization Phase

Changes in infants' looking during familiarization provide understanding into how easily they represented the stimuli presented during familiarization. Three aspects of infants' behavior during habituation were analyzed. First, we analyzed the number of trials infants required to reach criterion. If the commonalities in one condition were more difficult for infants to learn, infants should take more trials to reach the habituation criterion. A t test comparing the number of trials to criterion in the two conditions revealed no significant difference in the number of trials to reach criterion by infants in the appearance constant condition ($M = 19.33$, $SD = 5.07$) and in the

Table 2
Mean Looking Times (in Seconds) for the First and Last Familiarization Block (Standard Deviations in Parentheses) by Experiment and Familiarization Condition

	Block	
	First	Last
Experiment 1	71.47 (32.92)	39.41 (16.97)
Appearance constant	82.08 (25.02)	46.54 (15.64)
Function constant	60.85 (37.33)	32.28 (15.71)
Experiment 2	79.61 (34.45)	44.59 (23.32)
Appearance constant	79.61 (33.58)	48.88 (25.99)
Function constant	77.97 (34.45)	40.31 (20.12)
Experiment 3	79.28 (26.03)	59.62 (26.16)

function constant condition ($M = 15.00$, $SD = 7.46$), $t(22) = 1.66$, $p = .11$, two-tailed.

We also analyzed the duration of infants' looking during habituation. The average duration of infants' looking in the first four and last four habituation trials was entered into a mixed-model analysis of variance (ANOVA) with condition as the between-subjects variable and block (first, last) as the within-subjects variable. It is not surprising that this analysis revealed a main effect of block, $F(1, 22) = 31.52$, $p < .001$, showing that infants did indeed decrease their looking during the familiarization phase (see Table 2). This analysis also revealed a main effect of condition, $F(1, 22) = 4.37$, $p < .05$. During the familiarization phase, average trial durations (collapsed across blocks) for infants in the appearance constant condition were longer ($M = 16.08$ s, $SD = 6.83$) than for infants in the function constant condition ($M = 11.64$ s, $SD = 7.90$).

Finally, we compared the total duration of infants' looking during habituation in the two conditions. Consistent with the analyses just described, comparison of the total duration of infants' looking in the two conditions during the familiarization phase revealed that infants in the appearance constant condition accumulated more looking ($M = 334.37$ s, $SD = 122.67$) than did infants in the function constant condition ($M = 202.97$ s, $SD = 178.09$), $t(22) = 2.10$, $p < .05$, two-tailed. It is well established that infants have increased looking time when presented with more complex stimuli that are difficult to process (Cohen, 1991). Therefore, on the basis of the duration of looking during familiarization alone, we conclude that learning the category in the appearance constant condition was more difficult, and we predict that in this condition infants will first learn the exemplars and only later form a summary representation, whereas infants in the function constant condition will first form a summary representation and only later learn the individual exemplars.

Test Phase

To establish what infants in the two conditions actually learned during familiarization, we evaluated their looking times to the four tests. First, infants' looking to the four tests were entered into a mixed-model ANOVA with familiarization condition and habituation status (habituated vs. failed to habituate) as the between-subjects variables and test (familiar, novel appearance/familiar function, familiar function/novel appearance, completely novel) as the within-subjects variable. This analysis revealed a significant Familiarization Condition × Habituation Status interaction, $F(1, 20) = 4.92$, $p < .05$. Infants in the appearance constant condition looked longer during test (averaged across the four tests) if they failed to habituate ($M = 16.98$ s, $SD = 9.81$) than if they did habituate ($M = 12.56$ s, $SD = 6.86$). Infants in the function constant condition, in contrast, looked longer during test on average if they did habituate ($M = 14.53$ s, $SD = 7.58$) than if they did not habituate ($M = 7.58$ s, $SD = 8.00$). This effect did not interact with test trial, however, and thus it has little impact on our main conclusions. It is generally consistent with the results from the familiarization phase, suggesting that the two familiarization conditions lead to different kinds of processing.

The analysis also revealed a significant main effect of trial, $F(3, 60) = 6.63$, $p < .001$. Post hoc comparisons of the means using Tukey–Kramer revealed that infants' looking to each of the novel items was significantly greater than that to the familiar item, $p < .05$ (see Figure 3). Thus, in general, infants dishabituated to all the novel stimuli presented during test.

The logic of this experimental design, however, was to evaluate infants' responding to each of the tests in each of the conditions. We evaluated infants' increase in looking to each of these items by conducting planned two-tailed t tests comparing their looking to each novel item with their looking to the familiar item. These comparisons revealed that infants familiarized with items similar in appearance significantly increased their looking to the item with a familiar appearance and novel function, $t(11) = 3.77$, $p < .01$; to the item with a novel appearance and a familiar function, $t(11) = 2.82$, $p < .05$; and to a completely novel item, $t(11) = 2.76$, $p < .02$. Infants familiarized with items similar in function increased their looking to an item with a familiar appearance and novel function, $t(11) = 3.55$, $p < .01$;

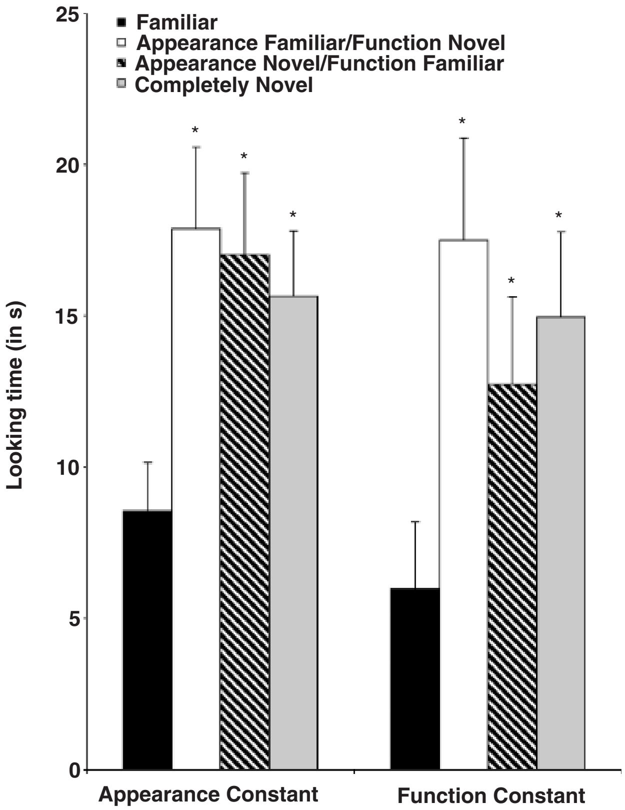


Figure 3. Looking times (in seconds) during test for the appearance constant and function constant conditions of Experiment 1. Significant increases in looking to novel stimuli relative to the familiar test are indicated by an asterisk. Error bars represent +1 *SE*.

to an item with a novel appearance and familiar function, $t(11) = 2.82$, $p < .05$; and to a completely novel item, $t(11) = 3.26$, $p < .01$.

Discussion

Two aspects of infants' responding in Experiment 1 are important. First, infants responded to changes in appearance and changes in function. In other words, infants in both conditions appeared to learn both the feature that the objects had in common and the features that individual objects had. A similar pattern was recently reported by Casasola and Cohen (2002) for infants' categorization of events based on spatial relations (e.g., ''in'').

Second, infants in the two conditions accumulated different amounts of looking during familiarization. Specifically, infants in the appearance constant condition, who were exposed to a single appearance and four different functions, looked much longer during familiarization than did infants in the function constant condition, who were exposed to a single function and four different appearances. This difference in looking times during familiarization suggests that infants were responding to the two categories differently. It is unclear, however, why infants in the appearance constant condition looked longer when the information about objects' appearances was constantly available during the entire trial—unlike the information about objects' functions that must be integrated across space and time. Infants in the appearance constant condition may have looked longer because of differences in the difficulty of processing function and appearance. If the appearance constant condition is more difficult for infants to learn, either because learning four functions is more difficult than learning one function or because function is more salient, we should find that categorization in the appearance constant condition unfolds in a different way than does categorization in the exemplar constant condition. Specifically, following the logic of Smith and Minda (Minda & Smith, 2001; Smith & Minda, 1998; Smith, Murray, & Minda, 1997), infants in the appearance constant condition should show an exemplar to summary representation shift, and infants in the function constant condition should show a summary representation to exemplar shift.

However, because the infants in Experiment 1 were very familiar with the familiarization stimuli—accumulating well over 200 s of looking on average during familiarization—these results do not reveal whether infants first formed a summary representation or first represented the individual exemplars. Thus, in Experiment 2 we probed infants earlier in learning by replicating Experiment 1 using a different habituation criterion. The goal was to make it easier for infants to reach the habituation criterion so that we could probe their learning after they had habituated but before they had accumulated as much looking during familiarization as did the infants in Experiment 1.

Experiment 2

Method

Participants

Participants were 36 healthy, full-term, 10-month-old infants ($M = 43.26$ weeks, $SD = 1.23$ weeks, range = 41.43 weeks to 45.43 weeks; 18 girls, 18 boys) with no history of birth complications or vision problems. Infants were predominately from White middle-class families. All of the mothers had graduated from high school, and 66.66% had completed at least a bachelor's degree. Three additional infants were tested but their data were not included in the final analyses because of experimenter error.

Stimuli, Apparatus, and Procedure

The stimuli, apparatus, and procedure were the same as in Experiment 1 except for two changes. First, the trials were 45 s in duration rather than 30 s in duration. We were concerned that in Experiment 1 infants failed to habituate in part because they did not have sufficient time on each trial to encode fully a stimulus. Indeed, 16 infants looked the full duration on at least some trials in Experiment 1. Second, we changed the habituation criterion. In Experiment 2, infants received the familiarization stimuli until they met the habituation criterion or until they received a maximum of 16 familiarization trials. Habituation was determined using sliding-trial-block habituation criterion: The habituation phase continued until infants' looking on any block of four trials was 50% of that exhibited on the first block. Blocks were defined as any four successive trials: Trials 1 to 4 constituted Block 1, Trials 2 to 5 constituted Block 2, and so on. This made it easier for infants to meet the habituation criterion. Indeed, in the appearance constant condition in this experiment, 61% of infants met the criterion (compared with 50% of infants in the appearance constant condition in Experiment 1), and in the function constant condition, 78% of infants met the criterion (compared with 75% of infants in the function constant condition in Experiment 1). Thus, we did make it easier for infants to reach the habituation criterion in the appearance constant condition but had little effect on their habituation in the function constant condition (note that infants were not necessarily any more habituated in Experiment 2 than in Experiment 1; rather, the changes we made helped infants reach our habituation criterion without fussing).

Results

Familiarization Phase

The number of trials to criterion was not different in the appearance constant condition ($M = 12.57$, $SD = 3.59$) and function constant condition ($M = 10.78$, $SD = 4.15$), $t(34) = 1.38$, $p = .18$. Note that although infants in the appearance constant condition still had on average more trials to reach criterion, the difference between the two groups was less pronounced. Moreover, infants habituated in fewer trials in this experiment, suggesting that using a sliding block to evaluate habituation did indeed help infants reach the habituation criterion.

The duration of infants' looking in the first four and last four familiarization trials was entered into a mixed-model ANOVA with condition as the between-subjects variable and block (first, last) as the within-subjects variable. This analysis revealed a main effect of block, $F(1, 34) = 35.58$, $p < .001$. Thus, infants in both conditions decreased their looking from the first block of trials to the last block of trials. Furthermore, the ANOVA failed to reveal a Block $\times$ Condition interaction ($p > .54$); that is, there was no difference in infants' decrease in looking as a function of their familiarization condition.

Comparison of infants' total amount of looking during familiarization once again revealed a significant effect of condition, $t(34) = 2.11$, $p < .05$, two-tailed. As in Experiment 1, infants in the appearance constant condition accumulated more total looking ($M = 212.77$ s, $SD = 97.09$) than did infants in the function constant condition ($M = 156.76$ s, $SD = 61.21$). In addition, the infants in this experiment exhibited much less looking during familiarization than did infants in Experiment 1. Thus, although infants habituated more quickly in this experiment than in Experiment 1, we tested their recognition of appearance and function changes after less time studying the familiarization set. Therefore, the test phase described next probed infants' knowledge earlier in the learning process, and any difference between Experiments 1 and 2 are likely due to differences in the point during learning at which their knowledge was probed.

Test Phase

The mean looking times to the four tests for each condition are presented in Figure 4. It can be seen that the two groups responded in the same way: Regardless of familiarization condition, infants increased looking to the object with a novel function but not to the object with a novel appearance. Indeed, the ANOVA conducted on the four test items revealed only a main effect of test trial, $F(3, 96) = 10.37$, $p < .001$. Once again, there was no effect of habituation status or condition on infants' responding during test. Tukey–Kramer comparisons among the means revealed that infants looked longer at the familiar appearance/novel function and at the completely novel than at the familiar test or the novel appearance/familiar function ($p < .05$). The differences between the novel appearance/familiar function and the familiar item, and between the familiar appearance/novel function and the completely novel were not significant.

Two-tailed t tests evaluating infants' increase in looking to each of the novel items in each condition confirmed that infants in both conditions increased their looking to the item with the familiar appear-

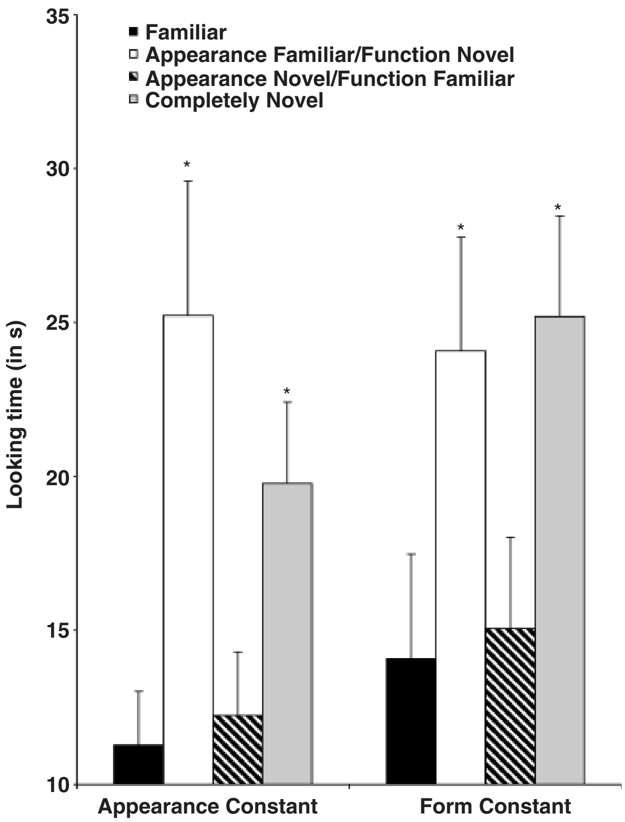


Figure 4. Looking times (in seconds) during test for the appearance constant and function constant conditions of Experiment 2. Significant increases in looking to novel stimuli relative to the familiar test are indicated by an asterisk. Error bars represent +1 *SE*.

ance/novel function, $t(17) = 3.24$, $p < .01$, for the appearance constant condition, and $t(17) = 2.27$, $p < .05$, for the function constant condition, and to the completely novel, $t(17) = 3.89$, $p < .001$, for the appearance constant condition, and $t(17) = 3.28$, $p = .004$, for the function constant condition, but not to the item with the novel appearance/familiar function (all ps > .66). Thus, infants in both conditions increased their looking to the stimulus that was novel in terms of function but not to the stimulus that was novel in terms of appearance.

Discussion

Both groups of infants in Experiment 2 increased their looking to an object with a familiar appearance and novel function but not to an object with a novel appearance and a familiar function. Recall, however, that this change in function reflected different changes in terms of the category infants learned during familiarization. That is, infants in the appearance constant condition increased their looking to a novel exemplar from the same category to which they were familiarized, consistent with their having remembered the individual exemplars. In contrast, infants in the function constant condition increased their looking to a novel exemplar from a novel category, consistent with their having formed a summary representation of the category to which they were familiarized. The combined results of Experiments 1 and 2, therefore, suggest that both of the patterns described earlier characterize infants' learning of a category. When presented with some stimuli (in these experiments stimuli that vary in function but share a common appearance), infants learn the unique items early in learning (Experiment 2), and later they attend to both the common feature and the unique items (Experiment 1). When presented with other stimuli (in these experiments stimuli that vary in appearance but share a common function), infants learn the common feature early in learning (Experiment 2) and the unique items later in learning (Experiment 1). Thus, infants familiarized with a category organized around a common appearance first learn individual exemplars and then form a summary representation, and infants familiarized with a category organized around a common function first form a summary representation and then learn individual exemplars.

These two patterns are consistent with Smith and Minda's (Minda & Smith, 2001; Smith & Minda, 1998; Smith et al., 1997) argument that the particular pattern of category learning varies with the context. In the present experiments, the category presented in the function constant condition may have been particularly difficult to learn, thus eliciting the summary-to-exemplar shift. Alternatively, the results of Experiment 2 may simply reflect infants' initially attending to and learning functional information, and only later attending to and learning appearance information. This alternative possibility is addressed in Experiment 4, and the relation between these two possibilities is discussed in more detail in the General Discussion.

Note, however, that even in Experiment 2 infants in the appearance constant condition again accumulated significantly more looking time during familiarization than did infants in the function constant condition. Although this difference is consistent with our speculation that the category in the appearance constant condition is more difficult to learn, it also raises the possibility that infants in the two conditions actually exhibited the same pattern of learning, but we probed them at different points in learning about the category. Infants in the appearance constant condition may simply have been further along in learning about the category than were infants in the function constant condition. In this case, if we probed infants in the appearance constant condition even earlier in learning (e.g., after they had accumulated about the same amount of looking as did the infants in the function constant condition in Experiment 2), we should find that they also respond to the common feature and not to the individuals.

Infants in the appearance constant condition in Experiment 2 accumulated approximately the same amount of looking as did infants in the function constant condition in Experiment 1, and yet these two groups appeared to have learned different things about the category. It seems more likely, therefore, that infants learn the category in the appearance constant condition differently from the category in the function constant condition, and even if we probed infants earlier in learning in the appearance constant condition they would respond to the unique features and not the common feature. We evaluated this possibility in Experiment 3 by testing infants in the appearance constant condition and probing their learning at the same point in processing as the infants in the function constant condition in Experiment 2.

Experiment 3

Method

Participants

Participants were 18 healthy, full-term, 10-month-old infants ($M = 43.76$ weeks, $SD = .96$ weeks, range $= 41.71$ weeks to 45.57 weeks; 11 girls, 7 boys) with no history of birth complications or vision problems. Infants were predominately from White middle-class families. All of the mothers had graduated from high school, and 94% had completed at least a bachelor's degree. Two additional infants were tested but their data were not included in the final analyses because of fussiness ($n = 1$) or looking the maximum possible amount of time on each test trial ($n = 1$).

Stimuli, Apparatus, and Procedure

The stimuli, apparatus, and procedure were the same as in Experiment 1 except that infants were familiarized with exactly eight familiarization trials and infants were only tested in the appearance constant condition.

Results

Familiarization Phase

Infants' looking during familiarization did decrease from the first block of four trials ($M = 19.82$ s, $SD = 6.51$) to the second block of four trials ($M = 14.90$ s, $SD = 6.54$), $t(17) = 3.52$, $p < .01$, two-tailed. However, only 3 of the 18 infants tested exhibited a decrease of at least 50% in looking duration from the first to the second block. Infants in this experiment accumulated only 126.89 s ($SD = 76.72$) of looking during familiarization; therefore, we did probe infants' learning earlier than in Experiments 1 or 2.

Test Phase

The goal of this experiment was to evaluate any differences in infants' responses in the appearance constant condition if infants were tested after less familiarization. The means for the four tests (presented in Figure 5) revealed that infants increased their looking to the item with the familiar appearance/novel function, $t(17) = 2.15$, $p < .05$, two-tailed, and to the completely novel, $t(17) = 2.19$, $p < .05$, two-tailed, but not to the item with the novel appearance/familiar function, $p > .58$. Thus, the pattern found for infants in the appearance constant condition in Experiment 2 was replicated, and infants in that condition appeared to learn initially the individual exemplars. These results do not support the

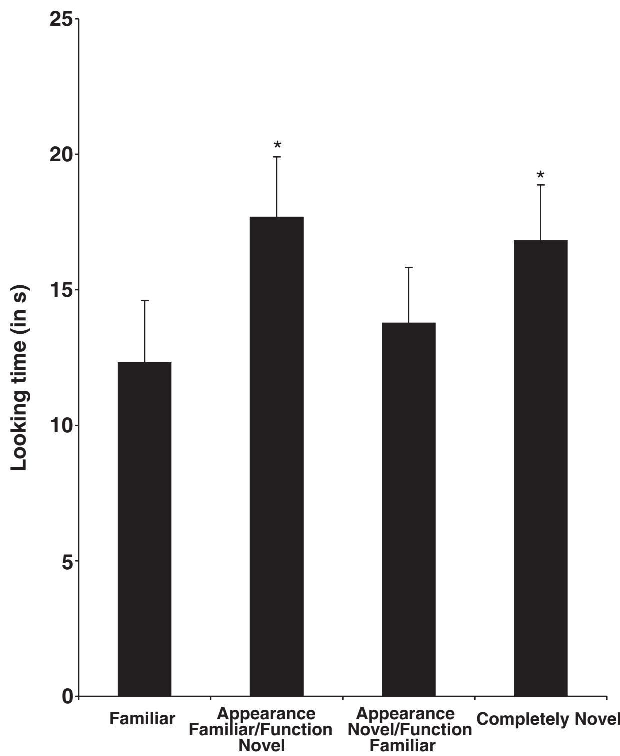


Figure 5. Looking times (in seconds) during test for Experiment 3. Significant increases in looking to novel stimuli relative to the familiar test are indicated by an asterisk. Error bars represent +1 *SE*.

conclusion that the differences between the appearance constant and function constant conditions found in the previous experiments can be attributed to the shorter familiarization times of infants in the function constant conditions. Rather, the pattern of category learning depends on the features of the stimuli and the category.

Comparison of Habituators and Nonhabituators

We conducted one additional set of analyses to address a potential alternative explanation for our results. Specifically, it is possible that the differences observed were the result of systematic differences between infants who habituated and infants who failed to habituate. That is, because none of our analyses revealed effects of habituation status, all of our results are reported by combining the data from infants who met the habituation criterion with infants who failed to meet the habituation criterion. Several studies indicate that infants' responding during test is a function of their level of habituation: More fully habituated infants respond differently to novel items than do less fully habituated infants (e.g., Courage & Howe, 1998, 2001). In particular, infants who are not fully habituated tend to prefer familiar items and infants who are more fully habituated tend to prefer novel items (Richards, 1997; Rose et al., 1982). It is possible, therefore, that our results report an averaging of two distinct patterns and that we simply did not have the power to detect differences between habituators and nonhabituators in the individual studies.

To rule out the possibility that infants who fully habituated were responding to novelty and infants who were less fully habituated were responding to familiarity, we compared infants' looking on the last familiarization trial before the test phase and on the test trial with the familiar item. We classified each infant in all three experiments as a habituator or nonhabituator by evaluating the amount of decrease in looking from their first block of three trials to their last block of three trials. We compared blocks of three trials because (a) in Experiment 2, the smallest number of trial to reach criterion was six trials, and therefore using blocks of three trials allowed us to include all infants in this analysis, and (b) most studies using habituation of looking time in infants use blocks of three trials, and therefore infants in the present study who habituated according to this criterion would be comparable to habituators in most reported studies. Using these criteria, 41 infants habituated (19 in the appearance constant condition and 22 in the function constant condition) and 37 infants failed to habituate (29 in the appearance constant condition and 8 in the function constant condition). An initial analysis confirmed that there was no effect of condition on infants' looking during the last familiarization trial and the familiar test trial. Paired t tests (two-tailed) revealed no significant difference in infants' looking in the familiar test and in the last familiar trial for either the habituators, $t(40) = .96$ (last familiarization: $M = 7.79$ s, $SD = 4.88$; familiar test: $M = 9.19$ s, $SD = 8.75$), or the nonhabituators, $t(36) = -1.60$ (last familiarization: $M = 14.88$, $SD = 11.01$; familiar test: $M = 12.00$, $SD = 8.77$). Thus, neither group of infants increased their looking to a familiar stimulus (indeed, the nonhabituators actually decreased their looking to the familiar) and the results reported previously were not simply caused by nonhabituators exhibiting a familiarity preference.

Discussion

Taken together, the results from Experiments 1 through 3 suggest that category structure influences how infants form categories. When presented with categories organized around a common appearance, infants first learn individual exemplars (Experiments 2 and 3) and later form a summary representation (Experiment 1). When presented with categories organized around a common function, infants first form summary representations (Experiment 2) and later learn individual exemplars (Experiment 1). Thus, infants' categories unfold differently over time depending on the complexity of the category they are learning and whether category-relevant information is constantly available.

However, these results are consistent with an alternative explanation. Specifically, these results are also consistent with infants simply processing what objects can do (e.g., roll and click) before they process what the objects look like (e.g., pink tube shape). If this is the case, we should observe that infants process function first in any task; that is, the results we observed would not be specific to categorization but would rather reflect a general interest in function regardless of the task. However, if the results we observed reflect differences in how infants use function in forming categories of items, this pattern should be specific to a categorization task, and function should not have any special status in other tasks.

We examined this alternative in Experiment 4 by testing infants' discrimination of the individual items after varying amounts of familiarization. Across two experiments (Experiments 4a and 4b) we probed infants' learning at different points so that we could determine whether infants initially attend to function in any task with these stimuli, or whether the pattern of results was due to the role of function in categorization. This design allowed us to examine not only whether infants could discriminate between the different appearances and functions used in the previous experiments but also whether function is simply more salient than appearance regardless of the task or context.

Experiment 4

Method

The stimuli, apparatus, and procedure were the same as in the previous experiments except that following the pretest, infants in Experiment 4a were presented with exactly eight familiarization trials with a single object and infants in Experiment 4b were presented with exactly four familiarization trials with a single object. Each infant was shown a different object during familiarization so that every possible appearance-function change could be included at test. Thus, one infant saw the purple object roll, one saw the purple object shake, one saw the yellow object shake, and so forth. Immediately following the familiarization phase, infants received four test trials: (a) one trial with the stimulus presented during habituation (the familiar test trial); (b) two trials with novel stimuli (order counterbalanced across infants)—the novel appearance/familiar function test involving an object with a novel appearance, but with the function they had seen during familiarization, and the familiar appearance/novel function test involving an object with the familiar appearance but a novel function; and (c) one trial with a completely novel stimulus (the border collie). The objects used to test infants' attention to appearance and function were counterbalanced across infants so that overall each possible change was tested. For example, four infants were familiarized with the purple object completing one of the possible actions, and then each of these infants was tested on a different change in appearance (multicolored, pink, pyramid, and yellow). Likewise, four infants were familiarized with an object that was rolled during familiarization, and then each of these infants was tested on a different change in function (invert, shake, squeeze, and pull).

Experiment 4a

Participants

Participants were 20 healthy, full-term, 10-month-old infants ($M = 43.79$ weeks, $SD = 1.22$ weeks, range = 41.71 weeks to 45.43 weeks; 10 girls, 10 boys) with no history of birth complications or vision problems. Infants were predominately from White middle-class homes. All of the mothers had graduated from high school, and 90% had completed at least a bachelor's degree. Five additional infants were tested but their data were not included in the final analyses because of fussiness ($n = 1$), equipment error ($n = 1$), or experimenter error ($n = 3$).

Results

Familiarization phase. Infants' looking decreased over the course of familiarization. Looking during the first block was significantly greater than looking during the second block, $t(19) = 6.28$, $p < .001$.

Test phase. To test infants' ability to discriminate the items, we evaluated their increase in looking to each of the novel test items by conducting planned t tests comparing their looking to those items with their looking to the familiar item (see Figure 6). Infants increased their looking to the novel appearance, $t(19) = 2.58$, $p < .05$; to the novel function, $t(19) = 4.00$, $p < .001$; and to the completely novel, $t(19) = 4.01$, $p < .001$. There were no differences in the

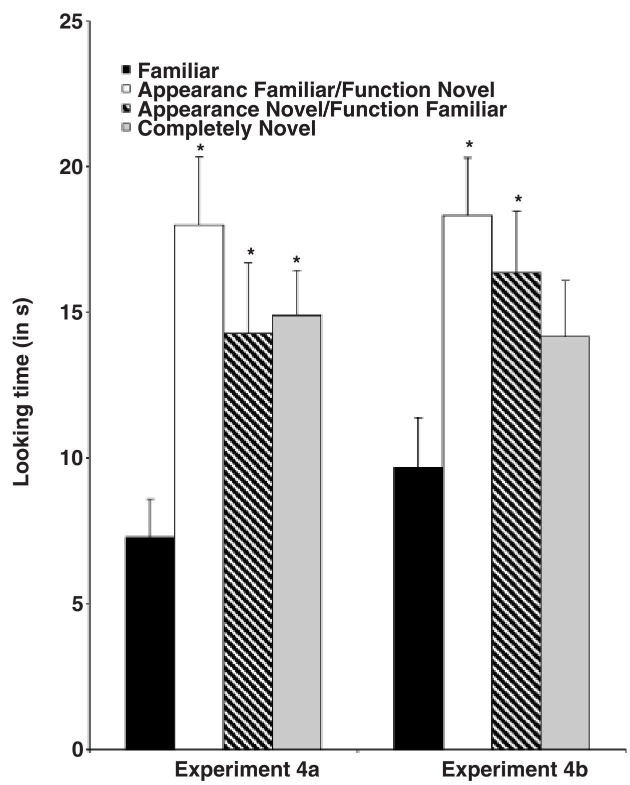


Figure 6. Looking times (in seconds) during test for Experiments 4a and 4b. Significant increases in looking to novel stimuli relative to the familiar test are indicated by an asterisk. Error bars represent +1 *SE*.

amount of time infants looked to changes in appearance or changes in function, $t(19) = 1.9$, *ns*.

Discussion

Infants were able to discriminate both a novel appearance and a novel function from the stimulus presented during familiarization. A remaining question is whether infants initially attended to and processed information about function and only later attended to and processed information about appearance. In Experiment 4b we evaluated this possibility by testing infants' recognition of a change in function or appearance after only four familiarization trials. If infants initially process information about objects' functions and only later process information about objects' appearances, after four familiarization trials infants should increase their looking to a novel function but not to a novel appearance. If, however, infants process both objects' functions and appearances from the beginning, infants should increase their looking to both a novel function and a novel appearance.

Experiment 4b

Participants

Participants were 20 healthy, full-term, 10-month-old infants ($M = 43.49$ weeks, $SD = 1.10$ weeks, range = 41.57 weeks to 45.43 weeks; 11 girls, 9 boys) with no history of birth complications or vision problems. Infants were predominately from White middle-class homes. All of the mothers had graduated from high school, and 90% had completed at least a bachelor's degree. Five additional infants were tested but their data were not included in the final analyses because of fussiness ($n = 1$), experimenter error ($n = 2$), or looking the maximum 30 s at test ($n = 2$).

Results

Familiarization phase. Infants' looking decreased over the course of familiarization. Looking during the first two trials was significantly greater than looking during the last two trials, $t(19) = 3.19$, $p < .01$.

Test phase. Infants' increased their looking to the novel items (see Figure 6); they significantly increased their looking to the novel appearance, $t(19) = 2.36$, $p < .05$, two-tailed, and to the novel function, $t(19) = 3.96$, $p < .01$, two-tailed. Although not significant, they did increase in looking to the completely novel, $t(19) = 1.61$, $p = .12$. Thus, after only four familiarization trials, infants noticed changes in both appearance and function. More important, there were no differences in infants' looking to a change in appearance or a change in function, $t(19) = .84$, *ns*. Thus, infants appear to process information about objects' appearances and functions quickly during familiarization.

Discussion

The combined results from Experiments 4a and 4b indicate that infants process information about objects' appearances and functions early. That is, we did not observe in a discrimination task that infants initially attended to function and only later attended to appearance, as they apparently did in the categorization tasks used in Experiments 1 through 3, confirming conclusions drawn by Quinn and Eimas (1998) that different processes govern object categorization and discrimination. Recall that the results found in Experiments 1 to 3 were consistent with two alternative explanations. First, infants may have formed exemplar-based categories when the category-relevant information is constantly available, as in the appearance constant condition, and formed summary representations when the category relevant information must be integrated across space and time, as in the function constant condition. Alternatively, infants in both conditions may have simply processed information about the objects' functions before processing information about the objects' appearances. The results of Experiments 4a and 4b make this alternative explanation unlikely. Because infants in these experiments increased their looking to changes in objects' appearances and functions, it does not appear that infants always initially respond to function and only later respond to appearance. Obviously, it is possible that if we could test infants after only one or two trials they may respond more to one kind of change than another. However, at present we have no evidence that infants initially attend selectively to function (or appearance) when learning about a single object, which suggests that their selective attention to function in the categorization tasks reported earlier reflects something about infants' categorization processes in particular and not something about the salience of functional properties in general.

General Discussion

These studies show for the first time how infants' categorization unfolds over time and reveal that whether infants first form a summary representation or first learn individual exemplars depends, in part, on the structure of the category to which they are exposed. Specifically, across three experiments we found that infants familiarized to a category based on static perceptual information (appearance) first learned the features of the individual exemplars and only later learned the common feature, but infants familiarized to a category based on dynamic features (function) first formed a summary representation and only later learned the individual items.

These results are consistent with two recent accounts of how categorization unfolds over time. First, these results are consistent with Smith and Minda's (1998) suggestion that category learning involves a summary representation (prototype) to exemplar shift, but that exemplars are also learned very early in processing difficult and sparse categories (Minda & Smith, 2001; Smith et al., 1997). In the present experiments, infants in the appearance constant conditions learned individual exemplars relatively early in learning (Experiments 2 and 3), but after more extensive familiarization they formed a summary representation and learned individual exemplars (Experiment 1). Infants in the function constant conditions formed a summary representation early in learning (Experiment 2) and after more extensive familiarization learned individual exemplars (Experiment 1). This pattern is consistent with categories defined by appearance being more difficult to learn.

Why would these categories be more difficult to learn? One possibility is that function is simply more salient than appearance. Specifically, the functional features of our stimuli were dynamic whereas appearance was static—recall that young infants are more attentive to dynamic than to static stimuli (Slater, 1989; Slater et al., 1985) and that infants can recognize objects from motion cues alone (Arterberry & Bornstein, 2002). In addition, the functional features were accompanied by a sound, and infants find changes in the auditory component of audiovisual events particularly compelling (Lewkowicz 1988a, 1988b; Robinson & Sloutsky, 2004). In addition, although dynamic features tend to be more salient than static features, they may be more difficult for infants to learn. In our stimuli, the functions are revealed over time; thus, to learn the functions infants needed to integrate information presented over time. Because such integration is presumably difficult for infants (Arterberry, 1993; Arterberry et al., 1993), it may be more difficult for infants to learn the functions in our stimuli than to learn the appearances.

These differences in salience and information-processing demands of function and appearance may contribute to differences in how easily infants can learn that a set of objects with similar appearance and different functions constitute a category as compared with learning that a set of objects with similar functions but different appearances constitute a category. In the appearance constant condition, it may have been difficult for infants to inhibit attending to and remembering the salient, difficult-to-process feature unique to each individual (function) and to learn the feature that was common across objects (appearance). Indeed, infants consistently accumulated more looking during familiarization in the appearance constant condition. Infants in this condition attended to the unique functions, apparently learning the individual exemplars first and only later forming a summary representation of the items. The function constant condition did not have such a conflict—the common feature was the more salient feature. It may be easier to form a category based on a common salient, difficult-to-process feature. In these experiments, when infants were faced with a category in which the individual items were unique in terms of the less salient, easier-to-process feature of appearance, they attended to the more salient, difficult-to-process common feature of function and formed a summary representation first. Only later in learning did they show evidence of remembering the individual appearances. Experiment 4 demonstrated that the initial selective attention to function appears to be specific to category learning tasks and does not emerge in tasks in which infants learn only about a single object. It is important to note that infants engaged in different processes of category learning when confronted with categories defined by different types of commonalities.

The present results are also consistent with Quinn's (2002) recent model in which infants' attention to individual exemplars versus a summary representation varies as a function of the category to be learned. In Quinn's framework, however, the differences in the pattern depend on how familiar infants are with the category in general. When first learning a category of items based on a small number of instances, infants initially learn individual exemplars. With more experience, infants form a summary representation. Finally, after extensive experience with a category, infants can both maintain a summary representation and remember individual exemplars. It is possible, therefore, that the different patterns observed here were a function of infants' familiarity with the type of category to be learned. From an early age, infants form appearance-based categories (Eimas & Quinn, 1994; Oakes et al., 1997; Quinn & Eimas, 1996; Quinn et al., 1993; Rakison & Butterworth, 1998). It is less clear when infants begin to form function-based categories. In studies using different procedures, infants learn and attend to appearance before function (e.g., see Madole, Oakes, & Cohen, 1993), and when learning the names of objects, 2- to 4-year-old children are biased to use appearance rather than function when generalizing novel nouns (Baldwin, 1989; L. B. Smith, Jones, & Landau, 1996; Yoshida & L. B. Smith, 2003). Thus, infants in the present experiment may have initially learned the exemplars in the appearance constant condition because that type of category is more familiar, and they may have initially formed a summary representation in the function constant condition because that type of category is less familiar.

In summary, these studies provide insight into how infants' categorization of objects unfolds over time. Specifically, consistent with models proposed by Quinn (2002) and Smith and Minda (1998), we found evidence that under some conditions infants' category learning progresses from learning exemplars to learning common features, and under other conditions infants' category learning progresses from learning common features to learning exemplars. These findings are predicted by a general framework that infants' categorization is flexible and context dependent (Oakes & Madole, 2000; Quinn, 2002; L. B. Smith & Jones, 1993). More precisely, these results demonstrate for the first time that aspects of the category structure determine how infants' categorization of those stimuli unfolds over time. Future research will need to address why appearance and functional features have different influences on infants' category formation. But the results reported here mark a critically important step in deepening our understanding of the nature of infants' categorization.

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