Published in final edited form as:

Dev Sci. 2009 January ; 12(1): 96–105. doi:10.1111/j.1467-7687.2008.00737.x.

Toddlers Can Adaptively Change How They Categorize: Same Objects, Same Session, Two Different Categorical Distinctions

Jessica S. Horst¹, Ann E. Ellis², Larissa K. Samuelson¹, Erika Trejo¹, Samantha L. Worzalla², Jessica R. Peltan², and Lisa M. Oakes¹

¹ University of Iowa

² Grinnell College

Abstract

Two experiments demonstrate that 14- to 18-month-old toddlers can adaptively change how they categorize a set of objects within a single session, and that this ability is related to vocabulary size. In both experiments, toddlers were presented with a sequential touching task with objects that could be categorized either according to some perceptually salient dimension corresponding to a taxonomic distinction (e.g., animals vs. vehicles) or to some less obvious dimension (e.g., rigid vs. deformable). In each experiment, children with larger productive vocabularies responded to both dimensions, showing evidence of sensitivity to each way of categorizing the items. Children with smaller productive vocabularies attended only to the taxonomically related categorical grouping. These experiments confirm that toddlers can adaptively shift the basis of their categorization and highlight the dynamic interaction between the child and the current task in early categorization.

Forming categories is fundamental for understanding the world. However, the features most important for categorization change from moment to moment—shape is relevant for the category “rolling objects,” but material is relevant for the category “objects that bang.” Moreover, individual objects can be included in different categories—a plastic ball can be categorized both with “rolling objects” and “objects that bang.” Skilled categorizers, therefore, must recognize features constant across members of a category, but overcome the tendency to perseveratively categorize using one set of features, adaptively shifting the basis of their categorization when appropriate. Such adaptability is likely related to the kind of flexible thinking that is a hallmark of executive function in children and adults (Jacques & Zelazo, 2005), increases with age (Jacques & Zelazo, 2001), and is impaired in patients with frontal lobe damage (Damasio, 1985).

Infants do categorize differently in response to task variations. For example, when familiarized with the exact same items, infants attended to a relatively broad category (e.g., animals) or narrow category (e.g., land animals) depending on which items were encountered frequently during familiarization (Oakes & Spalding, 1997). Infants familiarized with dogs or horses differentiated those categories when a novel dog and a novel horse were presented side-by-side, but not when the novel items were presented sequentially (Younger & Furrer, 2003). Toddlers categorized objects as animals and vehicles

Correspondences should be addressed to Lisa M. Oakes, who is now at the Center for Mind and Brain, University of California, Davis, California 95618 (lmoakes@ucdavis.edu).

Jessica Horst is now at the University of Sussex. Lisa Oakes is now at the University of California, Davis.

Portions of these data were presented at the 2003 and 2005 Biennial Meetings of the Society for Research in Child Development, Tampa, FL and Atlanta, GA.

only if the functional parts (e.g., legs and wheels) were in a standard orientation (Rakison & Butterworth, 1998a; 1998b).

Thus, young children adaptively categorize items in response to task and stimuli differences. However, skilled categorizers also group items along one dimension at one moment, and then switch to another dimension if the task changes. Mareschal and Tan (2007), using sequential-touching, found that 18-month-old toddlers adaptively first grouped objects into basic-level categories and later grouped those objects into global categories. Ellis and Oakes (2006) similarly observed that across four weekly sessions, 14-month-old toddlers categorized the same items as balls versus blocks *and* as rigid versus deformable when the rigid versus deformable distinction was demonstrated in each weekly session. However, this pattern was evident only in toddlers with relatively high receptive vocabularies; toddlers with lower receptive vocabularies focused only on the distinction between balls and blocks.

Here we used a procedure like that of Ellis and Oakes (2006) to observe adaptive categorization within a single session. We examined whether toddlers adaptively shift their attention from one categorical distinction to another on a moment-by-moment basis under several experimental conditions. In Experiment 1, we tested older toddlers using a different stimulus set than that used by Ellis and Oakes (2006) to explore whether the ability to adaptively categorize is robust and independent of the particular stimuli or point in development. In Experiment 2, we investigated whether younger toddlers' ability to adaptively change how they categorize arises spontaneously or emerges in response to the specifics of the task, for example, after seeing a demonstration designed to highlight a less obvious categorical distinction.

Experiment 1

Experiment 1 assessed 18-month-old toddlers' changing attention to the animal/vehicle and rolling/non-rolling object distinctions. Rakison and Butterworth (1998a; 1998b) observed that children at this age were sensitive to contrasts between animals versus vehicles and objects with legs versus wheels. Like Ellis and Oakes (2006), we included a vocabulary measure to test the relation between vocabulary and adaptive categorization. Based on that study, we predicted that vocabulary would be related to toddlers' attention to the less salient dimension, but not to their attention to appearance. Although Ellis and Oakes used receptive vocabulary, here we used productive vocabulary because (1) parental accounts of productive vocabulary have been found to be reliable (e.g., Dale, 1991; but see Dale, Bates, Reznick, & Morisset, 1989), and (2) measuring productive vocabulary is more appropriate for this age group. Because productive and receptive vocabularies are highly correlated (Fenson et al., 1994), the results we obtain here for productive vocabulary should be similar to those obtained by Ellis and Oakes with receptive vocabulary.

Method

Participants—Thirty-three healthy, monolingual 18-month-old toddlers participated (12 girls, 21 boys, $M = 78.46$ weeks, $SD = 1.60$ weeks, range: 75.50–84.10 weeks). Twenty toddlers (7 girls) were tested at the University of Iowa and 13 toddlers (5 girls) were tested at Grinnell College. The groups did not differ in age, vocabulary size, or number of touches (all p 's $> .11$). Data from two additional toddlers were excluded due to experimenter error and equipment failure. Here and in Experiment 2 children were recruited as reported by Ellis and Oakes (2006).

Stimuli—The stimuli were four animals (a tiger, an elephant, a horse and a giraffe) and four vehicles (a green car, a police car, a motorcycle and a bull-dozer), ranging from 8.50 cm to 16.50 cm in length and 3.30 cm and 16.50 cm in height (Figure 1). Each vehicle had visible

wheels, although only two had functional wheels (the wheels of the others were integral parts of the body and could not rotate). Two animals (tiger and elephant) had functional wheels that were almost completely hidden underneath the animal (only a fraction of the wheels was visible when the animal was on its side or upside down). Thus two animals and two vehicles could roll. Because the non-rolling vehicles had visible wheels and the rolling animals did not, no single visible feature reliably predicted rolling. A small wooden ramp was used to demonstrate rolling.

Procedure—Toddlers sat directly across from the experimenter, on a parent's lap or in a booster seat next to a parent. A video camera captured the child's head and upper body and the tabletop. Parents encouraged their children to play with the toys if necessary but avoided naming them. Parents completed the MacArthur-Bates Infant CDI.

Following two warm-up tasks (removing a poker chip from a bottle and stacking blocks, approximately 4 min), the experimenter dumped the toys onto a wooden tray (most toys were upright or on their sides; typically only the vehicles' wheels were visible), touched the objects (ensuring they were within the child's reach) and slid the tray to the child asking "Can you play with these?" The child was allowed to manipulate the objects for two minutes (timed with a hand-held stop-watch). The experimenter touched all the objects saying "Can you play with these?" when replacing any object that fell out of the child's reach, if the child failed to touch any objects, or if the child attended exclusively to one object. Otherwise the experimenter had minimal interactions with the child.

After two minutes, the experimenter retrieved the objects and, in a predetermined order (different for each child), demonstrated whether each object could roll. For each rolling object the experimenter (1) announced "Watch, this one rolls," (2) set it on the ramp, (3) retrieved it after it rolled down the ramp, (4) repeated the phrase and action, and (4) left the object at the foot of the ramp. For each non-rolling object the experimenter (1) announced "Watch, this one stops," (2) set it on the ramp, (3) after a pause repeated the phrase and action, and (4) set the object at the foot of the ramp. It was not clear whether this wording would influence toddler's performance—the 15 children reported to know the word "roll" and 23 children reported to know the word "stop" did not differ from those children who did not know either word in overall vocabulary, age, or performance in the main task. After the demonstration, a second two-minute sequential-touching phase was administered.

Coding—Naïve coders recorded the order of the objects touched for both sequential touching phases from videotape as described by Ellis and Oakes (2006). Two observers coded at least 20% of the videotapes for each study. Agreement for the order in which objects were touched was high, $M > 92\%$, $SD < 8.56$.

Results

We used several analytic strategies to examine our main prediction that vocabulary and adaptively shifting the basis of categorization would be related. From each infant's touching patterns, we calculated the traditional mean-run-length (MRL, e.g., Rakison & Butterworth, 1998a)¹ and the newer mean sequence-length (Mareschal & Tan, 2007; Thomas & Dahlin, 2000). MRL is calculated by dividing the total number of touches by the number of runs (sequences of touches to the same category—e.g., three successive touches to animals, four successive touches to things that roll). MSL is calculated by dividing a toddler's number of touches to a category by the number of runs to that category. Unlike MRLs, therefore, MSLs are based on a *category* (e.g., animals) rather than a *categorical distinction* (e.g., animals v.

¹We also calculated MRL used the method provided by Mareschal and Tan (2007). The same general pattern was observed.

vehicles). It has been argued that MSLs are more sensitive measures of infants' *categorization* because they are independent of behavior to other categories or overall number of touches. To allow comparisons to studies using both types of measures, we evaluated group responding using MRLs and individual infants' responding using MSL.

First, we calculated correlations between vocabulary and MRLs calculated separately for the appearance-based (animals vs. vehicles) and function-based (rolls vs. does not roll) distinctions before and after the demonstration (Table 1). Before the demonstration, neither MRL was related to vocabulary. After the demonstration, however, vocabulary was significantly correlated with both MRLs. Increases in vocabulary was associated with smaller appearance-based MRLs and larger function-based MRLs. Thus, infants with larger vocabularies appeared to be more attentive to function and less attentive to appearance after the demonstration than were toddlers with smaller vocabularies.

Second, we assigned toddlers to vocabulary groups based on a median split of their productive vocabularies (Table 2). This division resulted in two groups that differed significantly in productive vocabulary, $t(31) = 5.75$, $p < .0001$, $d = 1.98$, two-tailed, but not in age, $p > .70$.

A mixed-design Analyses of Variance (ANOVA) on the appearance-based MRL with Demonstration (pre-, post-) as the repeated measure and Vocabulary Group (high, low) as the between-subjects factor yielded no significant effects (Figure 2, left panel). Thus, in contrast with the correlations just reported, the ANOVA did not provide evidence that appearance-based MRL was related to vocabulary or the demonstration.

An identical ANOVA conducted on function-based MRLs, in contrast, was consistent with the correlations. The main effect of Vocabulary Group was significant, $F(1,31) = 4.49$, $p < .05$; high-vocabulary toddlers exhibited greater function-based MRLs than low-vocabulary toddlers (Figure 2, right panel). Interestingly, unlike the correlations, this effect was found for the means across the pre- and post-demonstration parts of the session. In general, then, both the correlations and this ANOVA revealed that attention to function was related to vocabulary, consistent with higher vocabulary toddlers being more adaptive.

This conclusion was corroborated with an examination of individual toddlers' touching patterns using the transitional probability of their mean sequence-lengths (MSL, Thomas & Dahlin, 2000). We calculated the probability that a toddler attended to each category (using $p = .10$, Mandler et al., 1987, Thomas & Dahlin, 2000). As a first step, we classified toddlers as *single* categorizers for a distinction (e.g., appearance) if they attended to only one category (e.g., animals but not vehicles), *dual* categorizers for a distinction if they attended to both categories (e.g., things that roll and things that do not roll), and *non-categorizers* for a distinction if they did not attend to either category.

The proportions of toddlers in each group are given in Table 3. Consistent with the analyses of the MRLs, the proportion of high-vocabulary toddlers attending to function (things that roll, things that don't roll) increased from 56.25% before the demonstration to 81.25% (single and dual categorizers combined) after the demonstration. The proportion of high-vocabulary toddlers attending to appearance (animal, vehicle) remained stable, as did the proportion of low-vocabulary toddlers attending to either appearance or function. Thus, these descriptive data confirm the conclusion from the group data; only high-vocabulary toddlers increased attention to function after the demonstration.

We can also examine how individual toddlers *changed* their categorization. First, we established children's pattern of attention *within* dimensions from before to after the demonstration: children could *increase* attention to appearance or function after the

demonstration (e.g., a single before and a dual categorizer after the demonstration), *decrease* attention to appearance or function after the demonstration (e.g., a dual before and a single categorizer after the demonstration), or be *stable* with respect to a dimension (exhibiting the same classification before and after the demonstration; toddlers who switched categories within a distinction—e.g. animals before and vehicles after the demonstration— but remained a single categorizer were classified as stable because they consistently attended to only one category). Note that children's change (or lack of change) with respect to one distinction was independent of their behavior toward the other distinction—e.g., a child could decrease attention to appearance and increase attention to function.

We then assigned children to one of three groups. *Function-focused* toddlers' attention to function increased while at the same time their attention to appearance decreased or remained stable. They effectively became more interested in function and less interested in appearance as the session progressed, adapting their categorization to the information provided in the task. *Appearance-focused* toddlers showed the opposite pattern—their attention to appearance increased or remained stable while at the same time their attention to function decreased or remained stable. They perseveratively attended to appearance despite the fact that the demonstration highlighted function. *Neither-focused* children did not fit either pattern (two children from the low vocabulary group never showed evidence of categorization and thus were not included in any of these groups).

Similar proportions of high- and low-vocabulary toddlers were neither-focused (see Table 4). However, more low-vocabulary children were appearance-focused than function-focused, primarily maintaining or increasing attention to appearance while decreasing attention to function. The high-vocabulary children, in contrast, generally maintained or increased attention function while decreasing attention to appearance. Thus, the analyses of the group data and of the individual data lead to the same conclusion: high-vocabulary toddlers were more likely than low vocabulary toddlers to adaptively categorize.

Discussion

These results demonstrate that toddlers can adaptively categorize the same objects in two ways within a single session. Eighteen-month-old toddlers with larger vocabularies were more likely than their peers to attend to function after a relevant demonstration.

In Experiment 2 we extended our understanding of this relation by conducting an experiment that would complement both Experiment 1 and the Ellis and Oakes (2006) study. Specifically, we sought to replicate the general finding from Experiment 1 with toddlers closer in age to Ellis and Oakes using the categorical distinctions used in that study. In addition, in Experiment 2 we examined whether adaptive categorization by 14- to 16-month-old toddlers is spontaneous or emerges as a response to the demonstration.

Experiment 2

Method

Participants—Twenty-three 14-month-old (9 girls, $M = 63.10$ weeks, $SD = 1.04$ weeks, range: 61.00–64.71 weeks) and twenty-five 16-month-old (15 girls, $M = 71.51$ weeks, $SD = 1.28$ weeks, range: 69.86–75.43 weeks) monolingual toddlers participated at the University of Iowa. Data from 5 additional toddlers were not included in the final analyses due to parental interference ($n = 2$), fussiness ($n = 2$), and lack of interest ($n = 1$).

Stimuli—The stimuli were four balls (a pink plastic ball, a blue foam ball, a green rubber ball and a white wiffle ball) and four blocks (a white fuzzy cube, an orange plastic block, a red plastic block and a plastic block with a picture on each side), ranging in size from 5.50

to 8.00 cm (see Figure 1).² Two objects from each group were deformable and two were rigid. The “frog” can-crusher used by Ellis and Oakes (2006) was also used.

Procedure—We administered two warm-up tasks: a tea party with the experimenter (approximately 2 minutes), and, as in Ellis and Oakes (2006), an animals/vehicles sequential-touching task (approximately 2 minutes). Note that because the animals/vehicles can be made on the basis of perceptual, conceptual or functional similarity, this initial task would not bias toddlers to attend to overall appearance or material, but rather would encourage them to touch the stimuli, therefore increasing their participation in our main task.

The main task was the same as Experiment 1 except that there were two demonstration conditions. In the *material demonstration* condition, the experimenter (1) placed the frog can-crusher on the table, (2) positioned ball and block inside the can-crusher saying “Look what this does!” and (3) attempted to squish it by pressing down on the can-crusher. In the *appearance demonstration* condition, the experimenter (1) held up each ball and block and (2) said “Look at this!” Note we still used two categorical distinctions in this study: one was apparent simply by looking at the objects (balls vs. blocks) while the other required the toddlers to interact with the objects (hard vs. soft).

Results

Initial analyses revealed no effect of age on performance, all p 's > .33; this variable was not included in any of the reported analyses.

As in Experiment 1, we examined group trends using MRLs and patterns of individual touching using MSLs. We conducted the correlations between appearance- and material-MRLs and vocabulary separately for the two demonstration conditions.³ None of these correlations were significant for the appearance demonstration condition (Table 1). In the material demonstration condition, in contrast, vocabulary was positively correlated with material-based MRLs after the demonstration. Thus, attention to the less obvious property appears to be related to vocabulary, but only if that property was demonstrated. Indeed, the correlation between vocabulary and material-based MRL for the material-demonstration condition was significantly greater than that for the appearance-demonstration condition, $Z = 2.47$, $p = .01$, two-tailed.

Next, we split the sample based on median vocabulary (see Table 6 for the resulting 4 groups). An ANOVA conducted on vocabulary scores with Demonstration Condition (material, appearance) and Vocabulary Group (high, low) as between-subjects factors revealed only a main effect of Vocabulary Group, $F(1,44) = 41.54$, $p < .0001$, confirming that the demonstration groups did not differ in vocabulary. The joint influences of vocabulary and demonstration on toddlers' adaptive categorization was examined with separate mixed-design ANOVAs on appearance- based and material-based MRLs with Demonstration (pre-, post-) as the repeated measure and Demonstration Condition and Vocabulary Group as between-subjects factors. The ANOVA on appearance-based MRLs yielded a Condition by Vocabulary Group interaction, $F(1,44) = 4.42$, $p < .05$, due to toddlers in the high vocabulary/ material demonstration group having the largest appearance-based MRLs ($M = 2.89$, $SD = 1.19$), followed by toddlers in the low vocabulary/

²These stimuli were a subset of those used by Ellis and Oakes (2006).

³In this experiment, as in Experiment 1, we used *productive* vocabulary as an indication of language development. However, Ellis and Oakes (2006) used *receptive* vocabulary with children of the same age and in essentially this same task. Indeed, the mean receptive vocabulary for children in Experiment 2 was 146.41, $SD = 81.24$, $N = 48$, 29-368 words, which is comparable to the receptive vocabulary scores obtained for children during their fourth visit in Ellis and Oakes (2006): 147.57, $SD = 66.16$, $N = 23$, 31-245 words. Moreover, the analyses reported here in Experiment 2 were also conducted using *receptive vocabulary*, and the same general pattern of results were found. For comparison to Experiment 1, we report the analyses using productive vocabulary.

appearance demonstration group ($M = 2.25$, $SD = .79$), the low vocabulary/ material demonstration group ($M = 2.20$, $SD = .95$) and the high vocabulary/appearance demonstration group ($M = 1.85$, $SD = .42$). This unexpected interaction did not appear to reflect the responding of the group as a whole. Rather, two children in the high vocabulary/ material demonstration group had appearance-based MRLs of > 7.66 before the demonstration. Thus, the significant interaction is neither clear nor meaningful. We elected to include the data from these toddlers in all the analyses, however, because their striking attention to appearance works against our hypothesis of attention to material.

As we expected, attention to material was restricted to high-vocabulary toddlers who saw the material demonstration. The ANOVA on material-based MRLs yielded only a significant Demonstration by Condition by Vocabulary Group interaction, $F(1,44) = 5.35$, $p < .05$. Separate ANOVAs conducted for each vocabulary group revealed no effects for the low vocabulary group, all $ps > .33$, but a significant Demonstration by Condition interaction for the high vocabulary group, $F(1,22) = 4.36$, $p = .05$. Thus, the type of demonstration influenced how material-based MRLs changed from before to after the demonstration for toddlers with higher vocabularies (Figure 3). We replicated Ellis and Oakes's (2006) finding that high-vocabulary toddlers attended to appearance before the demonstrations and material after the demonstrations. Individual infants' touching patterns using MSLs (see Table 3) revealed that in both demonstration conditions a relatively higher proportion of high-vocabulary children than low-vocabulary children attended to appearance both before and after the demonstration. In general, therefore, toddlers with larger vocabularies were more attentive to appearance similarities than toddlers with smaller vocabularies. In contrast, the proportion of toddlers who attended to material was not related to vocabulary size or demonstration condition.

Next, using the criteria described in Experiment 1, we classified toddlers as material-focused, appearance-focused, or neither-focused (data from two children—one in each of the low vocabulary groups in each condition—were excluded because they never showed evidence of categorization). Regardless of demonstration condition, high vocabulary toddlers were more likely than low vocabulary toddlers to be material-focused (see Table 5). Indeed, a 3-Way Contingency Test with Demonstration Condition (material, appearance), Vocabulary (high, low) and Focus Group (material, appearance) conducted on the subset of toddlers who did have a focus revealed a significant Vocabulary by Focus Group interaction, $G^2(1) = 3.94$, $p < .05$. Thus, vocabulary was related to toddlers' changing attention to material across the session. Toddlers with larger vocabularies were more likely to increase their attention to material than children with smaller vocabularies. The 3-Way Contingency did not reach significance, $G^2(4) = 5.96$, $p = .20$. Therefore, the evaluation of the individual touching patterns confirmed the conclusion from the analyses of the group performance that high-vocabulary toddlers were more attentive to the less obvious distinction than were the low-vocabulary. These analyses did not confirm, however, that this effect was primarily observed when that feature was actually demonstrated.

Discussion

Even young toddlers adaptively categorize within a single session. Such categorization is related to vocabulary level, and perhaps to the information provided in the task. Toddlers with larger vocabularies responded more to a less obvious material distinction than toddlers with smaller vocabularies. Evaluation of the group performance suggested that this relation between vocabulary size and attention to deformability was particularly strong when that distinction was demonstrated.

General Discussion

Toddlers are excellent categorizers. They can detect commonalities within and distinguish between categories. However, categories are not mutually exclusive; an object can belong to many categories at the same time. Which category is most relevant depends on the current situation. Thus, to be skilled categorizers, toddlers must be able to adapt their categorization strategy and the categorical distinctions to which they attend in response to task variations. We demonstrated that toddlers with relatively larger productive vocabularies adaptively categorized the same objects using a more obvious (e.g., shape) and to a less obvious (e.g., material) dimension in a single experimental session. Young children with larger productive vocabularies relative to their same-age peers have an impressive ability to quickly reorganize how they group objects.

There are at least three explanations for the link between vocabulary and adaptive categorization. First, adaptive categorization may emerge from language development. Learning the meanings of many different words requires that children attend to many different commonalities; consequently as they learn words, children may become sensitive to more types of commonalities. Indeed, as children's vocabulary increase, they can categorize objects in different ways (e.g., Balaban & Waxman, 1997; Waxman & Markow, 1995).

Second, the link between language and adaptive categorization may reflect advances in categorization abilities encouraging vocabulary development (see e.g., Gopnik & Meltzoff, 1987, 1992). Children's learning of new words may be made possible through toddlers' increasing sensitivity to new kinds of categorical contrasts. Regardless of the direction of the effect, the relation between vocabulary and adaptive categorization does not appear to reflect the relation between a specific language milestone and categorization. For example, our results do not reflect children who have achieved the vocabulary spurt (see, Goldfield & Reznick, 1990) demonstrating more adaptive categorization than children who have not. The vocabulary spurt is typically defined by the appearance of 50 words in the productive vocabulary. Our high vocabulary groups had fewer than 50 words in their productive vocabularies (indeed, only 19 toddlers in our entire sample produced 50 or more words); therefore, the relation we observed was not due to the high-vocabulary children having achieved this particular milestone and the low-vocabulary children having not yet achieved this milestone.

An even more striking illustration that adaptive categorization does not emerge once a particular language milestone has been achieved is a comparison of the low vocabulary group in Experiment 1 and the high vocabulary group in Experiment 2. Both groups of children produced approximately 30 words, and yet the group from Experiment 1 was less attentive to the less obvious distinction than was the group from Experiment 2. The point is that the same relation between children's vocabulary and adaptive categorization was observed at two points in vocabulary development (with infants of different ages), and with two different stimulus sets and categorical contrasts.

Rather than a direct link between vocabulary and adaptive categorization, the associations shown here may reflect the influence of another more general cognitive process on both vocabulary acquisition and adaptive categorization. Candidate processes are the ability to detect and attend to regularities, attention to salient cues, or general attentional capacity. Because here we observed the same relation between vocabulary and adaptive categorization at two different points in vocabulary development, our results are most consistent with this third alternative. If adaptive categorization was a product of language development, or if language development requires specific categorization skills, then vocabulary and

categorization should be related at one point in development—we should not see this relation re-emerging at different points in development. Of course, we did not directly examine cognitive ability. A clear direction for future research is to systematically investigate this possibility.

Why did adaptive categorization emerge at different points in development in the two experiments? Shifting the basis of the categories may have been more difficult in Experiment 1 for a number of reasons. The objects in Experiment 1 came from two superordinate categories, whereas the objects in Experiment 2 came from two basic-level categories. In addition, the items within the taxonomic categories of Experiment 1 may have been more variable than those within the shape categories of Experiment 2. Further, the less obvious distinctions in the two experiments are quite different, and the same skills and strategies may not be involved in these two groupings. Infants' categorization of stimuli depends on the interaction of factors such as infant age, stimulus presentation procedures, and stimulus variability (e.g., Bauer, Dow, & Hertzgaard, 1995; Mareschal, Quinn, & French, 2002; Oakes & Ribar, 2005). Nonetheless, our data clearly suggest that task variations led to differences in the level of adaptive categorization, even when toddlers had very similar vocabularies.

Interestingly, the evaluation of the group and individual performances did not always support the same conclusion. In general, toddlers with relatively high vocabularies were more attentive to the less obvious categorical distinction, even increasing attention to this distinction over time). However, in Experiment 2, examination of the group performance (using MRL) indicated that the type of demonstration played a role in this increase; examination of the individual touching patterns (using MSL) did not. MSL may be a better measure because it is more theoretically grounded and less arbitrary than MRL (Mareschal & Tan, 2007; Thomas & Dahlin, 2000). A full evaluation of the differences between these measures is beyond the scope of this paper. However, it is common to report both individual and group data when using sequential touching, and to draw conclusions from the general pattern (e.g., Mandler, Bauer & McDonough, 1991; Oakes et al., 1996). However, in the present experiments, conclusions about the effect of the different types of demonstration in Experiment 2 should be drawn with caution.

Overall, the present results suggest that adaptive categorization is a product of the interaction between the child and the task. This interpretation is consistent with a growing body of research suggesting that children's behavior should not be viewed as a reflection of static knowledge, but instead as a reflection of fluid and dynamic understanding that emerges in the moment as a product of the abilities the child brings to the task, what the child has just experienced, and the information available to the child in the task (e.g., Samuelson & Horst, 2007; Samuelson & Smith, 2000). Importantly, the present results suggest that understanding the development of these most fundamental aspects of cognition—such as adaptively categorizing in response to task variations—requires considering these complex child-task interactions.

Acknowledgments

This research and preparation of this manuscript were made possible by NIH grants, HD45713 to L.K.S., and HD49840, HD49143 and MH64020 to L.M.O. and grants to A.E.E. from Grinnell College. We would like to express our appreciation to Shaena Stille, Ryan Brink, Laura M. Phillip, Clay Y. Collins, Melanie K. Parker, Eleanora E. T. Cacciola and Marie Tan Kiak Li, as well as the undergraduate students in the Infant Perception and Cognition Laboratory, and the Language and Category Development Laboratory at the University of Iowa for their help with this project. We would also like to thank Prahlad Gupta for input into the design of Experiment 2, Sammy Perone for comments on an earlier draft of this paper, and the parents and children who participated.

References

- Balaban MT, Waxman SR. Do words facilitate object categorization in 9-month-old infants? *Journal of Experimental Child Psychology* 1997;64:3–26. [PubMed: 9126625]
- Bauer PJ, Dow GA, Hertzgaard LA. Effects of prototypicality on categorization in 1- to 2-year-olds: Getting down to basic. *Cognitive Development* 1995;10:43–68.
- Dale PS. The validity of a parent report measure on vocabulary and syntax at 24 months. *Journal of Speech and Hearing Research* 1991;34:565–571. [PubMed: 2072681]
- Dale PS, Bates E, Reznick JS, Morisset C. The validity of a parent report instrument of child language at twenty months. *Journal of Child Language* 1989;16:239–249. [PubMed: 2760125]
- Damasio, AR. The frontal lobes. In: Heilman, KM.; Valenstein, E., editors. *Clinical Neuropsychology*. New York: Oxford University Press; 1985. p. 339–375.
- Deak GO. The growth of flexible problem solving: Preschool children use changing verbal cues to infer multiple word meanings. *Journal of Cognition and Development* 2000;1:157–191.
- Ellis AE, Oakes LM. Infants' flexibly use different dimensions to categorize objects. *Developmental Psychology* 2006;42:1000–1011. [PubMed: 17087536]
- Fenson L, Dale PS, Reznick JS, Bates E, Thal D, Pethick S. Variability in early communicative development. *Monographs of the Society for Research in Child Development* 1994;59(5):v-173.
- Goldfield BA, Reznick JS. Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of Child Language* 1990;17:171–183. [PubMed: 2312640]
- Gopnik A, Meltzoff A. The development of categorization in the second year and its relation to other cognitive and linguistic developments. *Child Development* 1987;58:1523–1531.
- Gopnik A, Meltzoff A. Categorization and naming: Basic-level sorting in eighteen-month-olds and its relation to language. *Child Development* 1992;63:1091–1103.
- Jacques S, Zelazo PD. The Flexible Item Selection Task (FIST): A measure of executive function in preschoolers. *Developmental Neuropsychology* 2001;20:573–591. [PubMed: 12002094]
- Jacques, S.; Zelazo, PD. On the possible roots of cognitive flexibility. In: Homer, BD.; Tamis-LeMonda, CS., editors. *The development of social cognition and communication*. NJ: Lawrence Erlbaum Associates, Publishers; 2005. p. 53–81.
- Mandler JM, Bauer PJ, McDonough L. Separating the Sheep from the Goats: Differentiating Global Categories. *Cognitive Psychology* 1991;23:263–298.
- Mareschal D, Tan SH. Flexible and Context-Dependant Categorization by 18-Month-Olds. *Child Development* 2007;78(1):19–37. [PubMed: 17328691]
- Mareschal D, Quinn PC, French RM. Asymmetric interference in 3- to 4-month olds' sequential category learning. *Cognitive Science* 2002;26:377–389.
- Morales M, Mundy P, Rojas J. Gaze following and language development in six-month-olds. *Infant Behavior and Development* 1998;21:373–377.
- Oakes LM, Ribar RJ. A Comparison of Infants' Categorization in Paired and Successive Presentation Familiarization Tasks. *Infancy* 2005;7:85–98.
- Oakes LM, Spalding TL. The role of exemplar distribution in infants' differentiation of categories. *Infant Behavior and Development* 1997;20:457–475.
- Oakes LM, Plumert JM, Lansink JM, Merryman JD. Evidence for task-dependent categorization in infancy. *Infant Behavior and Development* 1996;19(4):425–440.
- Rakison DH, Butterworth GE. Infants' attention to object structure in early categorization. *Developmental Psychology* 1998a;34:1310–1325. [PubMed: 9823514]
- Rakison DH, Butterworth GE. Infants' use of object parts in early categorization. *Developmental Psychology* 1998b;34:49–62. [PubMed: 9471004]
- Samuelson LK, Horst JS. Dynamic Noun Generalization: Moment-To-Moment Interactions Shape Children's Naming Biases. *Infancy* 2007;11
- Samuelson LK. Statistical regularities in vocabulary guide language acquisition in connectionist models and 15–20-month-olds. *Developmental Psychology* 2002;38(6):1016–1037. [PubMed: 12428712]

- Samuelson LK, Smith LB. Grounding development in cognitive processes. *Child Development* 2000;77:98–106. [PubMed: 10836563]
- Singer-Freeman KE, Bauer PJ. Sorting out language and level: Examining the relation between productive vocabulary and category differentiation. *First Language* 1997;17:241–270.
- Thomas H, Dahlin MP. Inferring children's categorizations from sequential touching behaviors: An analytical model. *Psychological Review* 2000;107(1):182–194. [PubMed: 10687406]
- Waxman SR, Markow DB. Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology* 1995;29:257–302. [PubMed: 8556847]
- Younger BA, Furrer SD. A Comparison of Visual Familiarization and Object-Examining Measures of Categorization in 9-Month-Old Infants. *Infancy* 2003;4:327–348.

Figure 1. Stimuli used in both experiments. The left panel depicts the stimuli used in Experiment 1. The objects in front of the ramp can roll, the objects on the ramp cannot. The right panel depicts the stimuli used in Experiment 2. The objects to the right of the frog can-crusher are rigid, the other objects are deformable.

Figure 2. Average appearance-based MRLs (left panel) and function-based MRLs (right panel) for Experiment 1 by vocabulary group. Bars indicated by an asterisk were significantly different, $p < .05$. Error bars represent one standard error.

Figure 3. Average function-based MRLs for Experiment 2 by vocabulary level, demonstration group, and pre- versus post-demonstration. Error bars represent one standard error.

Correlations between productive vocabulary and MRLs before and after the demonstrations for Experiments 1 and 2.

Table 1

	Experiment 1				Experiment 2				
	Material Demonstration				Appearance Demonstration				
	r	p	N	r	p	N	r	p	N
Appearance MRLs									
Pre-Demonstration	-.04	.84	33	.17	.44	24	-.27	.21	24
Post-Demonstration	-.36	.04	33	-.13	.56	24	-.12	.57	24
Functional/Material MRLs									
Pre-Demonstration	.05	.79	33	-.02	.93	24	.22	.31	24
Post-Demonstration	.52	.002	33	.51	.01	24	-.17	.44	24

Table 2

Productive vocabularies for toddlers in Experiment 1. Toddlers' were assigned to the two groups based on the sample median and natural breaks in the vocabulary range.

	High Vocabulary Group	Low Vocabulary Group
Vocabulary		
<i>M</i>	105.38 words	27.76 words
<i>SD</i>	52.60 words	17.77 words
Range	55.00 – 219.00 words	2.00 – 49.00 words
Age		
<i>M</i>	78.86 weeks	78.09 weeks
<i>SD</i>	1.88 weeks	1.22 weeks
Range	76.43 – 84.10 weeks	75.50–80.29 weeks
<i>N</i>	16	17

Proportion of children who were classified as single, dual or none categorizers for the appearance and function/material dimensions in both experiments.

Table 3

	Experiment 1				Experiment 2			
	Material Demonstration		Appearance Demonstration		Material Demonstration		Appearance Demonstration	
	none	single	dual	none	single	dual	none	dual
Appearance Dimension								
<i>Low Vocabulary</i>								
Pre-demonstration	35.29	64.71	0.00	18.18	63.64	18.18	30.77	53.85
Post-demonstration	41.18	41.18	17.65	36.36	45.45	18.18	30.77	46.15
<i>High Vocabulary</i>								
Pre-demonstration	31.25	56.25	12.50	7.69	76.92	15.38	9.09	81.82
Post-demonstration	31.25	56.25	12.50	7.69	84.62	7.69	27.27	63.64
Function/Material Dimension								
<i>Low Vocabulary</i>								
Pre-demonstration	41.18	47.06	11.76	27.27	54.55	18.18	23.08	53.85
Post-demonstration	47.06	41.18	11.76	54.55	36.36	9.09	38.46	46.15
<i>High Vocabulary</i>								
Pre-demonstration	43.75	56.25	0.00	38.46	53.85	7.69	36.36	45.45
Post-demonstration	18.75	62.50	18.75	46.15	38.46	15.38	36.36	36.36

Table 4

Proportion of children who focused on appearance or function after the demonstration in Experiment 1.

Group		
Subgroup		
	Low Vocab	High Vocab
Function Focused	26.67	50.00
increase function, decrease appearance	13.33	18.75
stable appearance	6.67	18.75
stable function, decrease appearance	6.67	12.50
Appearance Focused	46.66	18.75
increase appearance, decrease function	13.33	6.25
stable function	13.33	12.50
stable appearance, decrease function	20.00	0.00
Neither Focused	26.67	31.25
decrease appearance, decrease function	6.67	0.00
increase appearance, increase function	6.67	6.25
stable appearance, stable function	13.33	25.00

Table 5

Proportion of children who focused on appearance or material after the demonstration in Experiment 2.

Group Subgroup	Material Demonstration		Appearance Demonstration	
	Low Vocab	High Vocab	Low Vocab	High Vocab
Material Focused	20.00	30.76	16.66	45.45
increase material, decrease appearance	10.00	7.69	0.00	18.18
stable appearance	0.00	7.69	8.33	27.27
stable material, decrease appearance	10.00	15.38	8.33	0.00
Appearance Focused	30.00	23.07	50.00	27.27
increase appearance, decrease material	10.00	0.00	0.00	0.00
stable material	0.00	7.69	25.00	18.18
stable appearance, decrease material	20.00	15.38	25.00	9.09
Neither Focused	50.00	46.15	16.67	27.27
decrease appearance, decrease material	10.00	0.00	16.67	0.00
increase appearance, increase material	10.00	7.69	16.67	9.09
stable appearance, stable material	30.00	38.46	0.00	18.18

Table 6

Productive vocabularies for toddlers in Experiment 2. Toddlers were assigned to the two groups based on the sample median and natural breaks in the vocabulary range.

Demonstration Condition		High Vocabulary Group	Low Vocabulary Group
<i>Measure</i>			
Material Demonstration			
<i>Vocabulary</i>	<i>M</i>	28.69 words	6.09 words
	<i>SD</i>	18.84 words	4.97 words
	Range	15.00 – 64.00 words	0.00 – 11.00 words
<i>Age</i>	<i>M</i>	68.16 weeks	66.16 weeks
	<i>SD</i>	4.41 weeks	4.37 weeks
	Range	61.86 – 73.86 weeks	61.57 – 72.57 weeks
	<i>N</i>	13	11
Appearance Demonstration			
<i>Vocabulary</i>	<i>M</i>	28.09 words	6.15 words
	<i>SD</i>	12.46 words	4.08 words
	Range	16.00 – 43.00 words	0.00 – 14.00 words
<i>Age</i>	<i>M</i>	68.56 weeks	67.64 weeks
	<i>SD</i>	3.90 weeks	4.94 weeks
	Range	62.57 – 73.57 weeks	61.00 – 75.43 weeks
	<i>N</i>	11	13