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SHORT REPORT

Highchair philosophers: the impact of seating context-dependent exploration on children's naming biases

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Abstract

We examine developmental interactions between context, exploration, and word learning. Infants show an understanding of how nonsolid substances are categorized that does not reliably transfer to learning how these categories are named in laboratory tasks. We argue that what infants learn about naming nonsolid substances is contextually bound – most nonsolids that toddlers are familiar with are foods and thus, typically experienced when sitting in a highchair. We asked whether 16-month-old children's naming of nonsolids would improve if they were tested in that typical context. Children tested in the highchair demonstrated better understanding of how nonsolids are named. Furthermore, context-based differences in exploration drove differences in the properties attended to in real-time. We discuss what implications this context-dependency has for understanding the development of an ontological distinction between solids and nonsolids. Together, these results demonstrate a developmental cascade between context, exploration, and word learning.

Introduction

Psychologists have long appreciated the role of context in learning and memory; learning and being tested on information in the same environment facilitates memory retrieval (see Smith & Vela, 2001, for review). Children too can use context to aid word learning and retrieval (Samuelson & Smith, 1998; Vlach & Sandhofer, 2011). Likewise, context can cue the appropriateness of various actions in adults and children. For example, infants learn that kicking activates a mobile in some crib contexts but not others (Butler & Rovee-Collier, 1989), and toddlers learn to reach for a ball with one or two hands for a ball depending on the sound played in a darkened room (Clifton, Rochat, Litovsky & Perris, 1991). The impact of context on children's understanding of different kinds of categories and how they are named has been relatively unexplored, however. We examine this issue in the domain of ontological kinds. Prior work has examined children's understanding of the difference between solid objects and nonsolid substances (e.g. Soja, Carey & Spelke 1991). We focus on the role of context and the activities that different contexts afford in toddlers' learning about this ontological distinction.

There are perceptual differences between solid objects and nonsolid substances that lead to an early appreciation of their distinction. Infants dishabituate to scenes of liquids after habituating to solids and vice versa (Hespos, Ferry & Rips, 2009). Similarly, infants appear to quantify solids and nonsolids differently, attending to differences in number of solid objects but not of nonsolid substances (Huntley-Fenner, Carey & Solimando, 2002). However, research on children's knowledge of how these kinds are *named* presents a more complicated picture. In fact, children's knowledge of the ontological distinction, and especially nonsolids, appears perturbed by word learning (Samuelson, 2002).

By 4 years of age, children demonstrate biases to attend to similarity in shape when generalizing names of novel solid objects and to similarity in material when generalizing names of nonsolid substances (Subrahmanyam, Landau & Gelman, 1999). However, development of these biases is not equivalent: the material bias is less

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robust (see Samuelson & Horst, 2007) and has been argued to be much later-acquired (Samuelson & Smith, 1999). Samuelson and Horst (2007) found that task structure and stimuli configuration affect novel noun generalization (NNG) for nonsolid substances. For example, 24-month-olds' material bias depended on exemplars being presented in pieces (rather than whole novel shapes). In contrast, the shape bias is so strong that 24-month-olds stick with shape even when solid stimuli are named with a mass noun (Soja, 1992) and children sometimes overgeneralize the shape bias to naming nonsolid and deformable stimuli (Samuelson, 2002; Samuelson, Horst, Schutte & Dobbertin, 2008).

Why is the material bias so fragile? Differences in the types of words that children learn early are likely part of the answer. In English, most words children learn by 30 months of age are count nouns naming solid objects in categories organized by similarity in shape (Samuelson & Smith, 1999). Children learn few mass nouns naming nonsolid substances in categories organized by similarity in material. Furthermore, the correlation between solidity and category organization on the 'shape side' of the vocabulary is very strong with much less overlap on the 'material side' (Samuelson & Smith, 1999). This structure helps children understand how categories of solid objects – but not nonsolid substances – are named (see also Perry & Samuelson, 2011). In addition, the names for nonsolids that children do learn early are a restricted set: 12 of 14 name foods (Table 1). Thus, the majority of children's experiences with, and knowledge about, nominal categories of nonsolid substances are constrained to a specific context – that of mealtimes.

Critically, the mealtime context is quite different from the typical laboratory NNG task. At home during meals, many toddlers sit in a highchair and are able to touch and play with their food; breaking it into pieces and eating it. In the laboratory, toddlers are usually seated at a table, and while they are allowed to touch stimuli, they are prevented from changing their configuration or eating them. Thus, the highchair is a context that allows children to gather kinds of information about substances that are different from the laboratory context. This is critical because information gained through active manual exploration is sometimes essential to knowing what something is. Imagine trying to determine which of two cups of white fluid and was milk and which was glue. Static visual information alone would be of little help, but inserting a finger into one cup would quickly clarify. Tactile information is generally more informative when classifying and naming materials (cf. Lederman & Klatzky, 1990). Mealtime, where toddlers often feed themselves pieces of food with their hands, is one context where exploring nonsolid substances is tolerated. Thus because the mealtime context provides opportunities for exploration of nonsolids not available in other circumstances, it may be especially potent in directing children's attention to similarity in material.

Table 1 *MCDI nouns that name nonsolid substances according to Samuelson and Smith's (1999) adult judgments of solidity*

Noun	MCDI category
Applesauce	Food
Coffee	Food
Coke	Food
Drink	Food
Jelly	Food
Juice	Food
Milk	Food
Pudding	Food
Sauce	Food
Soda/pop	Food
Soup	Food
Water	Food
Rain	Outdoor things
Water	Outdoor things

In the current study we ask how the behavioral context of mealtime (i.e. sitting in a highchair, being presented with food in piles/pieces) interacts with how children explore novel nonsolids and generalize names for them. We compare naming and similarity judgments of 16-month-old children when seated in a highchair versus a table. We picked this age because while they can do a standard NNG task, it is not until after 16 months of age that children typically show naming biases in the laboratory (see Samuelson, 2002; Samuelson & Smith, 1999) and are likely transitioning between highchair and table seating at home. We propose that sitting in a highchair in lab will lead to increased generalization by material similarity for nonsolid substances in a naming context, especially when stimuli are presented as pieces. Furthermore, we propose that changes in generalization will come from changes in how children explore nonsolids in the highchair relative to a standard experimental setting. If children's material bias comes out of associations between action pattern (touching and eating) and context (highchair and pieces of food), then manipulating context should induce changes in the action pattern and subsequent changes in generalization.

Methods

Participants

One hundred and ten typically developing monolingual English-learning 16-month-olds participated. Thirtyeight children were dropped from analyses (Fussiness: 32,[1] only selecting objects on one side: 3, and equipment error: 3). Seventy-two children (36 females; *M* = 16 months, 14 days; range = 15 months, 12 days–17 months, 16 days) were in the final group. Children participated in one of four between-subjects conditions (18 each) differing in seating (highchair versus table) and naming (naming versus no-naming). Children were recruited from birth records. Informed consent was obtained from parents prior to the session. Children received a toy for participation.

Stimuli

Nonsolid foods were arranged on white paper plates (15 cm diameter). Six familiar and 24 novel substances were used to make two warm-up and eight test sets (see Table 2). Order of test sets was randomized across participants. Each set was composed of an exemplar, a material match (same substance, different shape) and a shape match (same shape, different substance). Warm-up sets consisted of two identical familiar substances that differed in shape and one completely different substance that matched in shape (e.g. chocolate pudding arranged in pieces, chocolate pudding in a squiggle, and oatmeal in pieces). For test sets, the material match matched the exemplar in material but not color, shape, and possibly flavor, while the shape match matched the exemplar in shape but not color and material (e.g. grape jelly in a figure-eight, strawberry jelly in pieces, and mustard in a figure-eight).

On half of all trials (whole trials), the exemplar was arranged in a novel shape, the shape match was arranged in the same shape, and the material match was arranged into four pieces (see Figure 1). On remaining trials (pieces trials), the exemplar was arranged into four pieces, the shape match was arranged into four pieces, and the material match was arranged into a novel shape. Whether specific exemplars appeared as wholes or pieces was counterbalanced across participants. Eight nonce words were used in the naming condition.

Procedure

On each trial the child was given the exemplar object and the two test items to explore for a minute. The experimenter encouraged the child to touch and eat all three. For warm-up trials in the naming conditions, the experimenter placed the test objects on a tray, held up the exemplar and said, ‘This is my pudding. Can you get your pudding?’ and pushed the tray forward. For test trials, novel names were used (e.g. ‘This is my kiv. Can you get your kiv?’). The procedure for no-naming conditions was identical, but without names, (e.g. ‘This is mine. Can you get yours?’).

Parents completed a questionnaire about children’s at-home mealtime behavior, including whether they sit in a highchair or booster seat and how messy they get. Parents’ descriptions of messiness were classified as not messy, somewhat messy, or very messy by a coder blind to experimental hypotheses.

Coding and analysis

Sessions were videotaped and coded offline. During exploration before each generalization trial we coded social behaviors – e.g. positive/negative affect, social referencing – and manual behaviors – e.g. examining, poking, grasping (see Table 3, and Horst & Samuelson, 2013). During generalization we coded the final choice (shape versus material). One-third of sessions were recoded for reliability; inter-coder agreement was 85% for the exploration period and 95% for choice coding. Differences were resolved via joint video review.

NNG results are reported as proportion shape choice to facilitate comparison to prior studies. We analyze generalization using mixed logistic regression to examine effects of seating and naming condition, home seating, and messiness in the lab and at home. We use this method because ANOVAs on categorical outcome

Table 2 *Foods used in stimuli sets*

Exemplar	Material match	Shape match
Blue Mayo	Red Mayo	Readiwhip
Strawberry Jelly	Grape Jelly	Mustard
Green Icing	Blue Icing	Butterscotch
Blueberry Syrup	Strawberry Syrup	Easy Cheese
Green Jello	Orange Jello	Ketchup
Cream of Wheat	Green Cream of Wheat	Chocolate Sauce
Red Wheatena Cereal	Wheatena Cereal	Pumpkin Pie Filling
Green Coconut	Coconut	Blueberry Pie Filling

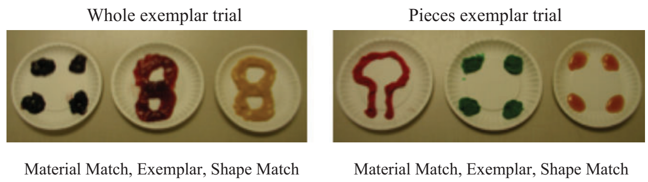
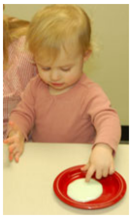
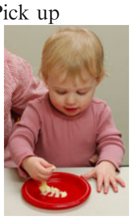
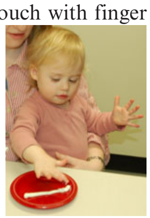
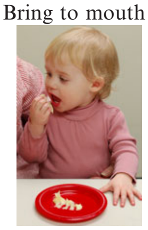


Figure 1 *Example stimuli sets used in experiment. Left panel shows a whole exemplar set; right panel shows a pieces exemplar set.*

[1] Participants were relatively young; thus the task might have been too demanding for some children.

Table 3 *Manual and social behaviors coded during the exploration period*

Manual actions			Social actions
Messy actions	Non-messy actions	Other actions	
Grasp 	Poke 	Examine Touch with hand Touch with object Look at object Bang Throw/drop Grouping	Positive affect Negative affect Engage adult Referencing Push away Request wipe Wipe off Experiment prompt Parent prompt
Pick up 	Touch with finger 		
Bring to mouth 			

variables are inappropriate (Jaeger, 2008; see also Perry, Samuelson, Malloy & Schiffer, 2010; Perry & Samuelson, 2011). We removed colinearity by sum-coding data and scaling continuous variables. To determine appropriate random effects, we began with completely specified random effects structures including random slopes for all variables in a given model. Using model comparison, we systematically removed uninformative random effects (cf. Jaeger, 2009). All final models included random intercepts for subject and items.

Results

Our goal is to understand how seating context, naming, and exploration interact to support children's in-the-moment attention to material when naming nonsolid substances. Thus we examine: (1) overall demonstration of a material bias in NNG, (2) the relation between sitting in a highchair and messiness via our questionnaire data and coding of manual explorations, and (3) whether differences in generalization relate to differences in exploration.

NNG performance

Overall means and standard deviations are provided in Table 4. When children were in a no-naming task in the highchair or at the table, they were generally more likely to choose material than shape, but not greatly so. However, when children were in a naming task, those at the table picked the material and shape matches equally but those in the highchair picked the material match, especially when the exemplar was presented in pieces. Thus, group averages suggest that seating, naming, and trial type contribute to children's attention to material similarity in NNG.

This was supported by a logistic mixed regression model of the interaction between seating (highchair, table), naming (naming, no-naming), and trial type (whole, pieces). The model revealed a significant three-way interaction, $z = -2{,}74$, $p < .01$, such that children in the highchair naming condition chose the material match more than other groups, especially on pieces trials. A chi-squared test comparing this model to similar models without seating condition, naming condition, or trial type revealed that models without seating condition,

Table 4 *Overall mean number of shape choices (and standard deviations) in the Novel Noun Generalization (NNG) task from the four seating and naming conditions for each trial type. Results reported as proportion shape response to facilitate comparison to similar studies*

	Trial	No-naming		Naming	
Table	Whole exemplar	.47 (.33)	.41 (.18)	.43 (.24)	.48 (.15)
	Pieces Exemplar	.36 (.20)		.53 (.22)	
Highchair	Whole exemplar	.41 (.26)	.42 (.20)	.49 (.28)	.37 (.17)
	Pieces Exemplar	.44 (.26)		.27 (.30)	

$X^2(1) = 12.12$ $p < .05$, naming condition, $X^2(1) = 9.68$, $p < .05$, or trial type, $X^2(1) = 8.73$, $p < .07$, were each worse than the full model. Thus all these factors are necessary to capture the pattern of data.

A model of only children in the naming condition revealed that those in a highchair were significantly more likely than those at the table to choose the material match, $z = -2.08$, $p < .05$. There was also a significant interaction such that those in the highchair were especially more likely to choose material on pieces trials, $z = -2.58$, $p < .01$. Conversely, a model of only children in the no-naming condition did not reveal any significant effects of seating, $z = .12$, *ns*.

A model of only those in the highchair condition revealed an interaction between naming condition and trial type such that those in the naming condition were marginally more likely than those in the no-naming condition to choose the material match on pieces trials, $z = -1.94$, $p = .052$. A model of only those in the table condition revealed an interaction between naming condition and trial type such that those in the naming condition were marginally more likely to choose the shape match on pieces trials, $z = -1.94$, $p = .051$. Together, these results demonstrate that the highchair context increases children's attention to material similarity – but only in the presence of names and stimuli in pieces.

Thus, as predicted, the early material bias is context-bound. This is clear in Figure 2, which shows the distribution of individual children's NNG performance on the pieces trials for each condition. That this systematic difference was found on pieces trials supports earlier research demonstrating the role of stimuli on NNG behavior (Samuelson & Horst, 2007). We add to this by showing that the context in which children typically learn names for nonsolids, a highchair, affects the way they generalize new names in the lab. However, to argue that this is about the developmental association between naming, nonsolids, and exploration in the highchair context, we need to examine how behavior at home relates to behavior in the lab.

Manual exploration

A linear mixed regression model on the parental questionnaire data with mealtime seating predicting messiness level revealed that children who sat in a highchair at home were the messiest eaters, $t = 6.22$, $p < .001$,[2] suggesting that the highchair affords action patterns that might be the basis for children's association of naming nonsolids and material similarity. To examine this we analyzed the amount of exploratory touching children demonstrated in the lab and its relation to the material bias. A linear mixed regression model predicting overall rate of manual exploration based on the interaction of naming and seating condition revealed that children in the highchair condition, $t = 1.42$, $p < .05$, and especially those in the highchair naming condition, $t = 1.72$, $p < .05$, engaged in more manual behaviors overall. This was not because the experimenter behaved differently, as there were no condition differences in social behaviors, $t = -.03$, or experimenter prompts, $t = .09$, *ns*.

A linear mixed regression model predicting rate of messy manual behaviors based on the interaction of seating and naming conditions showed that children in the highchair naming condition were more likely to engage in messy behaviors $t = 1.56$, $p < .05$. A model of the interaction between seating and naming conditions showed no differences in the amount of non-messy manual behaviors children engaged in, $t = .52$, *ns*. Further, children in the highchair naming condition were more likely to perform messy actions with the material match than children in other conditions, $t = 1.86$, $p < .05$, and marginally more likely with the shape match than children in other conditions, $t = 1.42$, $p < .10$. Children were equally likely to perform messy actions on the exemplar, $t = 1.08$, *ns*. Thus, because children in the highchair naming condition performed more messy behaviors with the two test stimuli, their exploration was more comparative. A remaining question is whether this comparison affected generalization.

Effects of manual exploration on generalization

A logistic mixed regression model of the effect of manual actions on generalization showed that the more messy

[2] Due to difficulty determining degrees of freedom in linear mixed models, we conducted MCMC sampling to find *p*-values (Baayen, Davidson & Bates, 2008).

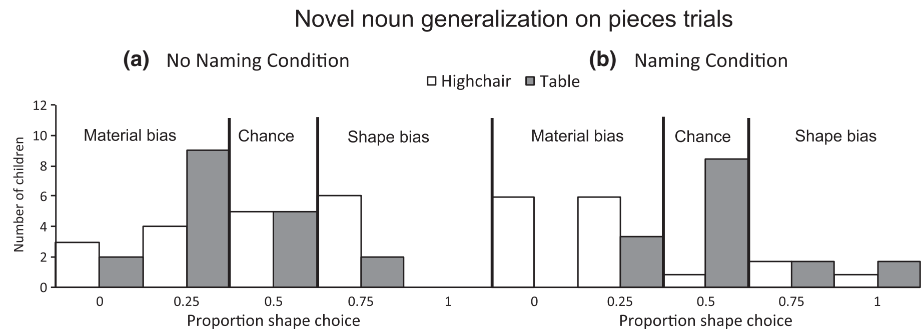


Figure 2 *Histogram of individual children's NNG performance by naming and seating condition for the pieces trials. As can be seen in Panel a, in the no-naming task children's patterns of behavior are distributed similarly when sitting in the highchair versus at the table. However, as can be seen in Panel b, in the naming task children in the highchair attend to material more than children at the table.*

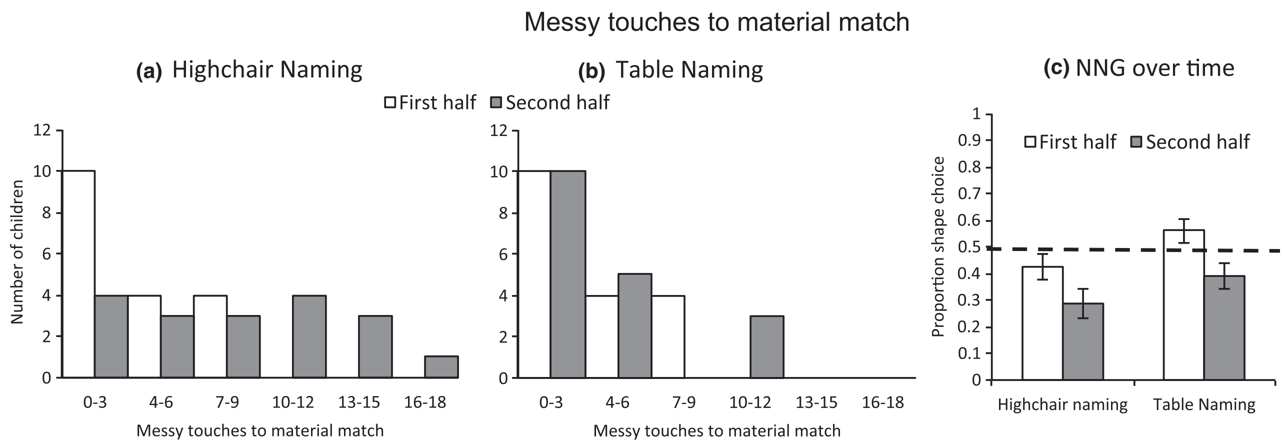


Figure 3 *Histogram of individual children's rate of messy touches in the highchair (Panel a) and table (Panel b) naming conditions early and later in the experimental session. As can be seen, children in the highchair increased their rate of messy actions as the experiment progressed, whereas children at the table did not. This resulted in even more NNG by material for these children in the second half of the experiment (Panel c). In Panel C we graph time as first half versus second half of the session for ease of visualization.*

behaviors a child directed towards the material match during exploration, the more likely she was to select the material match at test, $z = -2.38$, $p < .05$. Conversely, the more messy behaviors a child directed towards the shape match, the more likely she was to choose it, $z = 4.16$, $p < .0001$. Messy touches to the exemplar during exploration, however, were associated with being marginally more likely to choose the material match at test, $z = -1.83$, $p < .10$. Thus, children who messily explored the exemplar and the material match used material as the basis for generalization. Importantly, a mixed linear regression model of the interaction between messy actions and trial number revealed that children in the highchair naming condition were slightly more likely to perform messy actions with the material than the shape match overall, $t = 1.63$, $p = .105$, and this increased significantly over time, $t = 2.40$, $p < .05$. Children in the highchair no-naming condition also were increasingly messy with the material match over time, $t = 1.79$, $p < .10$. Neither the table naming, $t = .73$, *ns*, nor table no-naming group, $t = 1.12$, *ns*, showed increased messiness to the material match over time. Figure 3 captures this increase in messiness and material responding for those in the highchair and table naming conditions. Non-messy touching did not affect generalization, regardless of whether these touches were directed to the material match, $z = .96$, *ns*, shape match, $z = 1.19$, *ns*, or exemplar, $z = .25$, *ns*.

Summary

Overall then, we found that children in the highchair naming condition were most likely to demonstrate a material bias, especially on pieces trials. In addition, we found that children who sat in a highchair were messy explorers. Finally, we found that children in the highchair naming condition were most likely to perform messy actions and these increased over the experiment, resulting in more attention to material when generalizing names for nonsolids.

General discussion

Past research demonstrates that children's material bias when naming nonsolids is less robust than their shape bias when naming solid objects. This inequality is influenced by the context-dependency of early word learning. Nearly all early-learned names for nonsolid substances are foods. This constrains children's knowledge about nonsolids to a specific context – a highchair. When we test NNG in this context, we find that children act more knowledgably than in the typical table laboratory context. This context-dependent knowledge seems tied to manual exploration. In the developmental context in which children learn to name nonsolids, they can touch, eat, and be messy. These patterns of exploration are critical for learning about substances because visual cues can be ambiguous. Thus, what toddlers learn about exploring nonsolids is constrained to mealtimes, and knowledge of the names of nonsolids – inasmuch as it is tied to exploration – is constrained to the highchair. The highchair is a cue to a context-dependent action pattern that supports attention to material similarity.

The current study contributes to our understanding of the cascading influence of learning context in structuring knowledge and behavior across long-term and in-the-moment timescales by demonstrating how sitting in a highchair affects exploration and category knowledge. Typically, the phenomenon of context-dependent learning is conceptualized as better recall of specific information (e.g. the name of a substance) when study and text contexts match. In contrast, we have shown a role for context in supporting higher-order generalizations (e.g. material is central to naming nonsolids *in general*). These data complement research on word-learning biases in showing how regularities in children's learning environments influence the biases they develop (Perry & Samuelson, 2011; Perry *et al.*, 2010; Samuelson, 2002). That context plays a role in this process helps explain not only why the shape and material biases are so unequal early in development, but also how children begin to apply word-learning biases appropriately (cf. Jones and Smith, 1993).

In particular, the context-dependency of nonsolid substance knowledge may be beneficial to developing multiple word-learning biases. If attention to material is primarily important in one context, but attention to shape is important in many contexts, then toddlers, who are notoriously bad at attention switching, may need contextual support for directing attention appropriately with different kinds of stimuli. Initially, as we demonstrate in this paper, redundancy between learning-context (including seating, stimuli arrangement, and exploration), solidity, and category organization biases children's attention only when all cues overlap. Thus, the environment supports children's weak ability to direct attention.

If children's knowledge of nonsolids and naming is so embedded in action patterns associated with mealtimes, how do they ever learn names for nonsolids in other contexts? Other researchers have argued that as children develop, attention becomes tuned to increasingly subtle cues, leading to systematic word-learning biases for multiple kinds of categories (Jones & Smith, 1993; Yoshida & Smith, 2003). In addition, as children develop they gain more varied experience with nonsolids in non-food settings (e.g. sand, lotion). This fits with research about variability and learning that suggests that learning in multiple contexts facilitates deeper learning (Smith, 1982). Furthermore, variability has long been known to aid specifically in generalization because it helps learners abstract category-relevant properties (Perry *et al.*, 2010; Posner & Keele, 1968). Varied experiences should decrease the context-dependency of children's nonsolid knowledge, creating a more general material bias.

Our results also have implications for the debate on how children come to treat nonsolid substances as distinct from solid objects. On one account, an innately specified distinction between kinds is the basis for naming and syntactic differences. Specifically, solids are individuatable objects and nonsolids are not, and children learn both how these kinds are named (shape and material biases respectively) and their associated syntax (count vs. mass in English) based on this underlying universal distinction (Li, Dunham & Carey, 2009; Soja *et al.*, 1991). On another account, ontological distinctions emerge from learned perceptual and linguistic regularities (Colunga & Smith, 2005; Yoshida & Smith, 2003; Samuelson & Smith, 1999). The present data align with the latter. In particular, we demonstrated that knowledge about naming nonsolid substances is critically linked to the behavioral context in which nonsolids are experienced. In particular, the regularity in the early-learned vocabulary (most nonsolids are foods) co-occurs with the mealtime context (sitting in a highchair, seeing food in pieces), and messy manual exploration. Whether these cues were matched in the lab affected exploration and generalization. This demonstrates that knowledge is embedded in the rich multi-sensory experience of the mealtime context and is theoretically important in that it adds a role for context-dependent action patterns to earlier associationist arguments. Thus, children's understanding that solid objects and nonsolid substances are different kinds, and these kinds are named differently, is learned via context-dependent experiences with linguistic, perceptual, and category regularities.

Conclusions

This study shows the cascading influence that the context of everyday activities – such as mealtimes – has on children's exploration, attention, and word learning. When young children messily eat and explore food at each meal, they are learning both about individual foods and also about nonsolid substances more generally. Children may be doing more than just making a mess in the moment: they are forever changing their attentional biases and the way they will learn over development.

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