

Why are *dunkels* sticky? Preschoolers infer functionality and intentional creation for artifact properties learned from generic language

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ABSTRACT

Artifacts pose a potential learning problem for children because the mapping between their features and their functions is often not transparent. In solving this problem, children are likely to rely on a number of information sources (e.g., others' actions, affordances). We argue that children's sensitivity to nuances in the language used to describe artifacts is an important, but so far unacknowledged, piece of this puzzle. Specifically, we hypothesize that children are sensitive to whether an unfamiliar artifact's features are highlighted using generic (e.g., "Dunkels are sticky") or non-generic (e.g., "This dunkel is sticky") language. Across two studies, older—but not younger—preschoolers who heard such features introduced via generic statements inferred that they are a functional part of the artifact's design more often than children who heard the same features introduced via non-generic statements. The ability to pick up on this linguistic cue may expand considerably the amount of conceptual information about artifacts that children derive from conversations with adults.

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1. Introduction

Over the first few years of life, children encounter a great diversity of artifacts, from bottles and blankets to computers and game consoles to highways and bridges (Bloom, 2004; Margolis & Laurence, 2007; Norman, 2002). Even setting aside their sheer variety, artifacts are likely to pose a complex learning problem. Although they are each created for a specific purpose, often that purpose bears only a loose relationship to their external appearance (German, Truxaw, & Defeyter, 2007; Keil, Greif, & Kerner, 2007; Petrosky, 1994; cf. Gibson, 1986). Thus, when examining an unfamiliar artifact, it is often hard to tell (a) which features are functional and which are not, and (b) which features are part of its intentional design and which are the unintended result of sustained use, accidents, etc.

These ambiguities arise even in the case of relatively simple artifacts such as keys, paperclips, or erasers, whose perceptual features do not provide many useful clues to a naive user. For example, the irregular teeth on the shaft of a key might look like the result of some accident, but in fact they are intentionally created and essential to its function.

It is likely that children rely on a number of information sources to solve this learning problem. First, children learn about artifacts by observing and imitating others' actions on them (e.g., Carpenter, Call, & Tomasello, 2005; Gergely, Bekkering, & Király, 2002; Meltzoff, 1988; Williamson & Markman, 2006), perhaps especially when these actions are tailored to children's limited processing abilities (e.g., Brand, Baldwin, & Ashburn, 2002) and accompanied by ostensive signals such as direct eye contact (e.g., Csibra & Gergely, 2009). For example, a parent might call a toddler's name before slowly and deliberately demonstrating how to use an eraser on some pencil marks, thereby providing evi-

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dence about what this artifact is for. Second, adults might also describe artifact functions during the course of their conversations with children (e.g., Callanan, 1990; Callanan, Siegel, & Luce, 2007; Gelman, Coley, Rosengren, Hartman, & Pappas, 1998). For example, a parent might say, while pointing to a truck, that it “keeps cement in there, and it rolls to keep mixing it when it’s wet” (Gelman et al., 1998, p. 93). Third, some artifact features do have detectable affordances, in that their physical configuration suggests certain possibilities for action (Adolph, Eppler, & Gibson, 1993; Gibson, 1986). For example, thin, sharp edges might afford cutting (e.g., Needham & Baillargeon, 1997; Tzelnic, Kuhlmeier, & Hauser, 2008), hollow insides might afford containment (e.g., Hespos & Baillargeon, 2006), and rigid flat surfaces might afford crushing soft objects (e.g., DiYanni & Kelemen, 2008).

In this paper, we identify an important, and previously overlooked, source of information that children might also capitalize on when learning about artifacts. Our hypothesis is that children can infer whether an artifact’s features are intentional and functional from some of the more subtle aspects of how others talk about them. Specifically, children may be attuned to whether an artifact feature is described using kind-referring generic language (e.g., “Keys have a jagged edge”) vs. non-generic language (e.g., “My key has a jagged edge”). We hypothesize children are more likely to infer that a feature is *functional* (Experiment 1) and *intentional* (Experiment 2) if it is described as applying to an entire kind—even though the speaker makes no overt reference to functions or intentional creation.

This hypothesis is motivated by recent research suggesting that children construe the information they learn through generic language as “essential” or conceptually central (Cimpian & Markman, 2009, in press; Gelman, Raman, & Gentner, 2009; Hollander, Gelman, & Raman, 2009). For example, 4- and 5-year-olds who were told that *snakes* have holes in their teeth construed this novel feature as an enabler of other important biological processes (e.g., it helps them chew better), whereas children who were told that *a particular snake* has holes in its teeth were more likely to construe this feature in terms of prior mechanistic processes (e.g., he bit on something pointy; Cimpian & Markman, 2009). In the artifact domain, generics’ essentialist implications might lead to the inference that the features talked about are related to the artifact’s intended function, which—at least on some accounts—is its essence (e.g., Bloom, 1996, 2004; German & Johnson, 2002; Kelemen, 1999; Kelemen & Carey, 2007; Matan & Carey, 2001; cf. Siegel & Callanan, 2007). For example, a child who hears that *keys* have a jagged edge might infer that this feature was intentionally created to serve a function and is not merely the byproduct of a process such as wear-and-tear.

Given its emphasis on learning from others, the spirit of our proposal is broadly compatible with sociocultural accounts of artifact cognition, according to which children learn about the uses of artifacts by observing and interacting with more knowledgeable members of their community (e.g., Callanan et al., 2007; Rogoff, 1990; Siegel & Callanan, 2007; Tomasello, 1999). Also consistent with our hypothesis are recent arguments to the effect that sub-

tle cues in adult-child conversations can be as valuable as explicit teaching because children often make inferences that go beyond what they hear rather than passively assimilating adult input in its exact form (Callanan, 2006; Gelman, 2009; Harris & Koenig, 2006; Keil, 1998; see also Cimpian, Arce, Markman, & Dweck, 2007; Kamins & Dweck, 1999).

Our strategy was simple: In both studies, we presented preschool-age children with unfamiliar artifacts and highlighted one of their features using either generic (e.g., “Dunkels are sticky”) or non-generic (e.g., “This dunkel is sticky”) language. In Experiment 1, we asked children to explain these properties and predicted that they would generate more functional explanations in the generic condition. In Experiment 2, we asked children whether the artifacts were “made like that” (i.e., with that feature) or whether “something happened”; here, we predicted that children would say the feature was created intentionally more often in the generic condition.

2. Experiment 1

2.1. Method

2.1.1. Participants

Forty-eight 4- and 5-year-old children participated (24 girls; mean age = 4;10; range = 4;0–5;8). An additional six children were tested but excluded because they did not complete the task. The children, all of whom were recruited in a small Midwestern city, were predominantly European American and came from a range of socioeconomic backgrounds.

2.1.2. Materials, design, and procedure

Children were randomly assigned to either the *generic* or the *non-generic* condition. These conditions differed only in the wording of the properties provided on each trial. The properties (e.g., being sticky) were chosen to be potentially—but not obviously—functional, and the artifacts were chosen to be unfamiliar to young children (see Fig. 1 for full list). On each of six trials, the experimenter first showed children a picture of an artifact and labeled it for them (e.g., “Okay, so now I want to show you this thing called a *dunkel*”). Children were then provided with the relevant property (e.g., “And here’s something interesting about *dunkels*/this *dunkel*. *Dunkels* are/This *dunkel* is sticky”), which was repeated once (e.g., “They are/It is sticky”). Finally, children were asked to explain this property (e.g., “Why do you think that is? Why are *dunkels*/is this *dunkel* sticky?”). The order of the six items was counterbalanced across children. The testing sessions were conducted either in the lab or in a quiet room at a school and were videotaped for later transcription.

2.1.3. Coding

Children’s explanations were coded for whether they made mention of a function (see Table 1 for examples). The coding was blind to the wording condition the responses came from. A second researcher coded 38 of the 48 transcripts to assess reliability. Agreement was 92.1%

ARTIFACT	PROPERTY	EXPERIMENT 1: Mean proportion (and SD) of functional explanations	EXPERIMENT 2: Mean proportion (and SD) of “made like that” responses
	G: <i>Bems</i> have a small gap at the tip.	.72 (.46)	.58 (.51)
	NG: <i>This bem</i> has a small gap at the tip.	.52 (.51)	.38 (.51)
	G: <i>Crullets</i> have a couple of cracks at the bottom.	.56 (.51)	.58 (.51)
	NG: <i>This crullet</i> has a couple of cracks at the bottom.	.39 (.50)	.15 (.38)
	G: <i>Dunkels</i> are sticky.	.48 (.51)	.50 (.52)
	NG: <i>This dunkel</i> is sticky.	.26 (.45)	.38 (.51)
	G: <i>Ludinos</i> have a bent tip.	.64 (.49)	.58 (.51)
	NG: <i>This ludino</i> has a bent tip.	.39 (.50)	.31 (.48)
	G: <i>Luzaks</i> have a hole in them.	.48 (.51)	.17 (.39)
	NG: <i>This luzak</i> has a hole in it.	.30 (.47)	.23 (.44)
	G: <i>Taifels</i> are flat.	.60 (.50)	.67 (.49)
	NG: <i>This taifel</i> is flat.	.30 (.47)	.31 (.48)

Fig. 1. The items used in Experiments 1 and 2. **G** and **NG** stand for “generic” and “non-generic,” respectively.

(kappa = .84), and disagreements were resolved by discussion.¹

2.1.4. Data analysis

In this study, as well as the next, our data were bimodal and thus violated the normality assumption required for parametric tests. Instead of ANOVAs, we used non-parametric ordinal logistic regressions (OLRs; for similar analyses, see Cimpian & Markman, 2009, in press) and Mann-Whitney *U* tests for follow-up comparisons.

2.2. Results and discussion

We performed an OLR on the number of functional explanations, using wording condition and gender as predictors. To explore developmental differences, we also divided children in each wording condition into a younger and an older group by a median split (mean ages = 4;5 and 5;3, respectively) and included age group as a predic-

tor in the OLR. The age groups were balanced in terms of gender composition.

Our prediction was that children would construe the features as functional more often in the generic than in the non-generic condition. This prediction was confirmed by a significant main effect of wording condition, Wald $\chi^2 = 4.12$, $df = 1$, $p = .042$. This effect, however, was qualified by a marginally significant interaction between wording condition and age group, Wald $\chi^2 = 3.25$, $df = 1$, $p = .071$. As shown in Fig. 2, the older children thought the novel features were functional more often in the generic ($M = 4.25$ on six trials) than in the non-generic ($M = 1.75$) condition, Mann-Whitney $Z = 2.31$, $p = .021$, Cohen's $d = 1.10$. In contrast, the younger children did not differentiate between the two conditions, $M_{generic} = 2.77$ vs. $M_{non-generic} = 2.64$, Mann-Whitney $Z = 0.21$, $p = .848$, Cohen's $d = 0.06$.²

These results suggest that, by age five, children use the generic/non-generic format of the language that describes an ambiguous property to infer whether it is functional.

¹ For a small number of explanations coded as functional (about 2%), it was ambiguous whether the key feature enabled the referred-to function or whether it was simply a byproduct of it. For example, if dunkels are sticky “because they’re for eating,” does their stickiness enable people to eat on/with them, or is it just a byproduct of eating on/with them? On the latter interpretation, the key feature per se is not functional. Importantly, our results are unaffected by whether these few ambiguous explanations are counted as functional or not.

² When children did not provide functional explanations, they often talked about the *prior causes* that led the artifacts to acquire the feature in question. For example, a taifel is flat because “maybe a steamroller came over it”; a crullet has a couple of cracks at the bottom because “someone broke it”; a dunkel is sticky “cause the dog chewed on it, maybe.” As one might expect, these explanations were more frequent in the non-generic ($M = 3.52$) than in the generic ($M = 1.88$) condition, Wald $\chi^2 = 5.65$, $df = 1$, $p = .017$. (Inter-coder agreement was 90.8%, kappa = .82.)

Table 1

Examples of functional explanations in Experiment 1.

<i>Bem/small gap at the tip</i>
So they can put fire out
So it can dig into things
You stick something in and you twist it around with that
Maybe because they have them because they need to do things
So it can make sounds
<i>Crullet/a couple of cracks at the bottom</i>
So when there's water, it will come out of the cracks
Well, 'cause, maybe, like, if they just needed a little bit of oil out, they could, like, pour some into it, and then it would drip out onto the thing they needed it on
Because something can, like, come out of it
So then if you're making coffee, then it will go out and into a mug, and then you can grind it up, and then it will become your coffee
Because you put wood in it, and then you push this thing, and then it cuts it into little straight lines of pieces [...]
<i>Dunkel/sticky</i>
Because they're supposed to stick to things
To help it stick to things
Because it's for a drink, and the drink might fall over because they're too big and it won't be ever steady, so that's why it's sticky so that drinks don't fall and stay on [...]
To stick onto things, windows
You can tape it on the wall and let it stick pictures on it [...]
<i>Ludino/bent tip</i>
So that if you drop your ring in the sink, you can get it out of the sink
To try to chop stuff
Because to pour stuff out
So for an old man, if he can't walk, it helps him walk, and he can put his hand there and then he walks like that, see? That's why it has a tip
So they can be pipes
<i>Luzak/hole</i>
So you can see through it
So that if people think they can play music with it, they can hold it with something
So you can put stuff in there
So you can stick your fingers inside
For decoration
<i>Taifel/flat</i>
So you can put it on stuff
Because maybe it's just a place to rest for tools
So you can lay it down and it doesn't roll around. Like, you can, like, just put it somewhere, and if there was to be an earthquake and if it were a round shaped, it would, like, roll around if you set it out on the back porch
Because it helps people hang sheets
Maybe you could put them on your head and they could be flat around like crowns

Experiment 2 tested whether children also use this semantic distinction to infer whether a feature was created *intentionally*. In addition, we sought to replicate the results of the first study by testing whether children assume that properties learned via generic language were created to *serve a function*.

3. Experiment 2

3.1. Method

3.1.1. Participants

Twenty-five 4- and 5-year-old children participated (13 girls; mean age = 4;8; range = 4;0–5;11). Their demographic characteristics were similar to those of the children in Experiment 1. None had participated in Experiment 1.

3.1.2. Materials, design, and procedure

The materials, design, and procedure were identical to those of Experiment 1, with one exception: Instead of being asked to explain the properties, the children were asked, e.g., “Do you think dunkels were/*this dunkel was made like that*—sticky—or did *something happen* to them/

it?” If the child chose “made like that,” then the experimenter asked a follow-up question: “And why were they/*was it made like that, do you think?*” So as not to single out “made like that” responses (and thus potentially influence children's subsequent choices), we also asked a question when they chose “something happened”: “And what do you think happened to them/*it?*” However, children's responses to this other question are not discussed here, as they are not pertinent to our argument.

3.1.3. Coding

Children's responses to the “Why were they/*was it made like that?*” follow-up questions were coded for whether they made mention of a function. A second researcher coded 20 of the 25 transcripts to assess reliability. Agreement was 97.5% ($\kappa = .89$), and disagreements were resolved by discussion.

3.2. Results and discussion

We first tested whether children assume that properties learned from generic language are more likely to be intentional. As in Experiment 1, we divided children in each

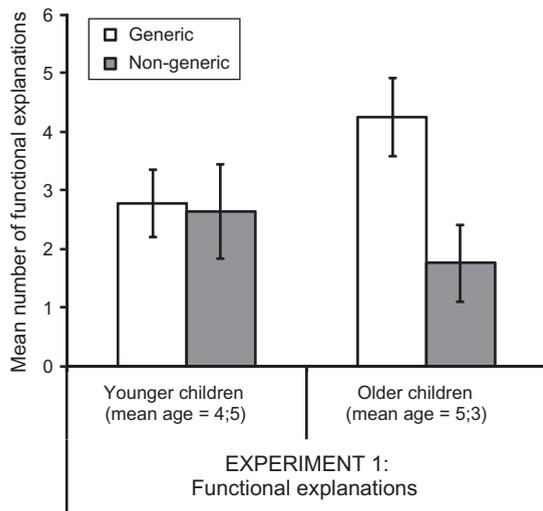


Fig. 2. The mean number of functional explanations produced in Experiment 1, by age group and wording condition. Error bars represent ± 1 SE.

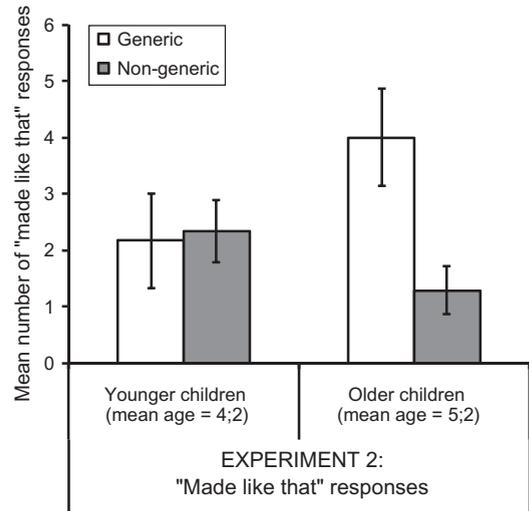


Fig. 3. The mean number of "made like that" responses produced in Experiment 2, by age group and wording condition. Error bars represent ± 1 SE.

wording condition into a younger and an older group by a median split (mean ages = 4;2 and 5;2, respectively). An OLR on the number of "made like that" responses with wording condition, age group, and gender as independent variables revealed the predicted main effect of wording condition, Wald $\chi^2 = 4.15$, $df = 1$, $p = .042$, which was again qualified by a wording condition \times age group interaction, Wald $\chi^2 = 7.06$, $df = 1$, $p = .008$. As shown in Fig. 3, the older children were more likely to think that a feature had been created intentionally if it was described in a generic statement ($M = 4.00$ "made like that" responses on six trials) than if it was described in a non-generic statement ($M = 1.29$), Mann–Whitney $Z = 2.17$, $p = .029$, Cohen's $d = 1.62$. The younger children showed no such difference, $M_{generic} = 2.17$ vs. $M_{non-generic} = 2.33$, Mann–Whitney $Z = 0.08$, $p = 1.00$, Cohen's $d = 0.10$.³

Next, we analyzed how often children said "made like that" and, in response to the follow-up question, provided a functional explanation. This conjunction of responses indicates that the relevant feature was construed as being intentionally created to serve a function. We were unable to analyze these responses with an OLR; this procedure cannot execute properly when there is a quasi-complete separation in the data (Albert & Anderson, 1984), which in our case occurred because children in the generic condition were the only ones who ever produced "made like that"-plus-function response combinations. We thus opted to test for generic/non-generic differences with a simple Mann–Whitney U test, collapsing across gender and age groups. As expected, "made like that"-plus-function conjunctions occurred significantly more often in the generic

condition ($M = 1.25$) than in the non-generic condition ($M = 0.00$), Mann–Whitney $Z = 2.53$, $p = .015$, Cohen's $d = 0.92$.⁴

In sum, 5-year-olds seem to assume that properties learned from generic language are part of an artifact's design rather than accidental or acquired aspects of it. Replicating the results of Experiment 1, children were also more likely to infer that the properties introduced via generics had been created to serve a function.

4. General discussion

Artifacts are "creations of the mind" (Margolis & Lau-rence, 2007)—objects created by psychological agents who intended them for a particular use. Thus, to understand an unfamiliar artifact, one has to decipher the intentions behind its creation. Often, however, this type of mentalistic "reverse engineering" is difficult because the intentions responsible for an artifact are not transparently reflected in its appearance. Despite our ability to perceive and exploit affordances (Gibson, 1986), the information that can be gleaned from perceptual inspection of many everyday artifacts is, in and of itself, not sufficient to identify their purpose—consider, for example, CDs, credit cards, or frisbees (e.g., German et al., 2007; Keil et al., 2007; Petrosky, 1994). Information other than directly perceived affordances must then factor into the process of learning the functions of artifacts. In this article, our hypothesis was that children may be able to pick up some function-relevant information from nuances in how adults talk about artifacts. Specifically, our studies showed that chil-

³ The OLR also revealed an unexpected interaction between age group and participant gender, Wald $\chi^2 = 6.45$, $df = 1$, $p = .011$. In the older group, the boys and girls were almost identical in the overall number of "made like that" responses, Mann–Whitney $Z = 0.00$, $p = 1.00$. However, in the younger group, boys were significantly more likely than girls to say "made like that," Mann–Whitney $Z = 2.64$, $p = .011$. The reason for this gender difference is unclear.

⁴ When children did not give a functional response to the "Why were they/was it made like that?" follow-up question, they again tended to talk about prior causes (that is, about how the object was made): for example, "because some people make them like this," "cause they built it like that," "because somebody bought them at the store and put sticky around them."

dren's thinking about unfamiliar artifacts is shaped by the generic vs. non-generic format of the language used to describe their properties, such that properties introduced generically are more often inferred to be a functional part of the artifact's intentional design.

The significance of generic language as a source of information about artifacts is determined not only by children's sensitivity to its implications but also by its frequency in the input. Generic statements about artifacts appear to account for approximately 1–1.5% of speech directed to children (e.g., Gelman, Chesnick, & Waxman, 2005; Gelman, Goetz, Sarnecka, & Flukes, 2008; Gelman et al., 1998), although their prevalence certainly varies depending on the activity (e.g., playing with toys vs. looking at pictures; see Gelman et al., 2005), the age of the children (e.g., Gelman et al., 2008), and so on. Assuming that parents produce around 10 utterances per minute during their conversations with children (Gelman, 2003; Stevenson, Leavitt, Roach, Chapman, & Miller, 1986), this percentage translates into an average of 6 to 9 generic sentences about artifacts per hour—by no means a trivial amount. In addition, even relatively little exposure to generic input may be quite powerful given the sparse structure of artifact concepts: For an artifact kind, the most important thing to be known about it is its intended function, arguably its essential dimension (e.g., Bloom, 1996, 2004; Matan & Carey, 2001). Thus, a *single* generic statement may be sufficient to clue children into the feature that enables this function (e.g., “Keys have a jagged edge”), thereby considerably limiting the space of hypotheses they would have to entertain.

The results also revealed a development in the ability to capitalize on the information implicit in these statements, in that only the 5-year-olds drew reliably different inferences from generic and non-generic statements. What could account for this difference? One possibility is that the younger group simply could not *distinguish* between the generic and the non-generic statements. However, since even younger children are quite adept at making this distinction (e.g., Cimpian & Markman, 2008; Cimpian, Meltzer, & Markman, in press; Gelman & Raman, 2003), this possibility is unlikely. The 4-year-olds probably understood the generic and non-generic statements as such—they were just not able to derive any additional inferences from them.

Another possibility is that the age difference was driven by developments in children's reasoning about artifacts. There is in fact some evidence that a full-blown understanding of the design stance—which encompasses the idea that an artifact's surface features are constrained by its intended function—develops over the preschool and kindergarten years (for a review, see Kelemen & Carey, 2007). Perhaps a firmer understanding of design might prompt children to infer that the reason why an entire artifact category possesses a feature (e.g., why dunkels are sticky) has to do with the function it was intended to fulfill. This hypothesis might also explain why studies that focused on generic statements about natural and social kinds (Cimpian & Markman, 2009, in press) found no consistent developmental differences in this age range. If an essentialist understanding of natural and social kinds is in place

earlier (e.g., Gelman & Wellman, 1991; Taylor, 1996; Taylor, Rhodes, & Gelman, 2009), then even 4-year-olds would be able to make use of this essentialist causal framework in interpreting generics about categories in those domains.

It is also possible that children need a certain level of cumulative exposure to generics about a domain (e.g., artifacts, natural kinds) before learning to draw additional inferences from these statements within that domain. That is, although children probably understand generic statements as referring to a kind regardless of the type of entity referred to, they may have to discover, domain by domain, what other kinds of inferences these statements license. Since parents tend to produce fewer generic statements about artifacts than about natural kinds (e.g., Gelman et al., 1998, 2005, 2008; see also Brandone & Gelman, 2009), this hypothesis may help explain not only why 4-year-olds' responses lagged behind 5-year-olds' in the current experiments (which dealt with artifacts), but also why 4- and 5-year-olds' responses were similar in domains with richer generic input (Cimpian & Markman, 2009).

A final possibility here is that 4-year-olds' competence was masked by some aspect of our task. For example, since our goal was to explore how the generic/non-generic distinction shapes children's thinking about objects whose function is unknown, we chose to use *novel* artifact categories. However, the studies that focused on natural and social kinds (Cimpian & Markman, 2009, in press)—and that did not find age differences—used familiar categories (e.g., snakes, boys). Thus, the younger children in the present studies may have simply been overwhelmed by the task of generating explanations for features of objects they had never seen before.

To conclude, our findings demonstrate that children apply their theory-building skills (e.g., Carey, 1985; Gopnik, Meltzoff, & Kuhl, 2001) not only to the direct evidence obtained from firsthand observation but also to the indirect evidence carried by what others say. Although, on the surface, a generic sentence such as “Dunkels are sticky” conveys a simple mapping between a property and an artifact category, children's understanding is not limited to this literal meaning. Instead, they go deeper and infer a *reason* for this mapping, which is that the referred-to property is a functional element of the artifact's design.

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