PERCEPTUAL PROPERTIES, CONCEPTUAL DOMAIN, AND THE ACQUISITION OF WORDS FOR SOLIDS AND NONSOLIDS

by

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Abstract

In 2 experiments, we taught 120 3-year-olds and 120 adults novel words for unfamiliar solid objects or perceptually similar nonsolid substances described as belonging either to the toy domain or the food domain. In a forced-choice task, participants extended the novel words to one of two test items: a same-shape test item (i.e., one that shared a common shape with the standard but differed in colour, texture, or smell) or a same-substance test item (i.e., one that shared a common colour, texture, and smell with the standard but differed in shape).

Participants made more same-shape choices in the solid than in the nonsolid conditions. This tendency varied depending on whether the same-shape item differed from the standard in colour, texture, or smell. Participants also made more same-shape choices for items described as toys than for the same items described as food. This tendency was consistent regardless of whether the same-shape item differed from the standard in colour, texture, or smell. The findings confirm previous reports that children’s word extensions are affected by the solidity of the referent. They also reveal that these extensions are guided by information about the referent’s conceptual domain. Finally, these results provide the first evidence that these extensions are influenced by the smell, texture, and colour of the referent.
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Perceptual Properties, Conceptual Domain, and the Acquisition of Words for Solids and Nonsolids.

Around the age of eighteen months, children start acquiring words at an amazing rate: almost one new word per waking hour, by one estimate (Carey, 1978). One of the ways in which children acquire these words is through ostensive definitions. Logically, learning words in this way results in an immense number of possible interpretations (Quine, 1960). For example, suppose a child sees a rabbit, and an adult points to it and labels it with an appropriate noun: “Look, it’s a rabbit!” When the child hears the word “rabbit”, she could (correctly) interpret this word as referring to a kind of animal, but she could also interpret it as applying to only this particular rabbit, to some rabbit part or portion, to a substance like fur, to some property like soft, or to an action like hopping. She could also extend this new word to anything associated with rabbits, like carrots or hutches. Despite this inductive problem, children seem to be very good at correctly picking out the referent of a new word and extending it to appropriate new instances. How do they do it?

A proposed answer to this question is that, in interpreting new words for solid objects, young children are guided by a number of constraints that serve to limit the possible interpretations they entertain. In one formulation of these constraints, Markman (1994; see also Golinkoff, Shuff-Bailey, Olguin, & Ruan, 1995; Waxman & Hall, 1993) proposed that children are guided by the whole object and taxonomic assumptions in their interpretations of new words for solid objects. The whole object assumption leads children to map a novel label onto an object in its entirety, rather than onto any part of it, the substance it is made of, or an action or relation in which it is involved. Together with the taxonomic assumption, the whole object assumption leads children to extend new words to other referents of the same kind as
the original referent rather than to other objects that are thematically linked to the original referent (e.g., to extend the word “shoe” to other shoes rather than to socks, feet, or walking). Similarly, Soja, Carey, and Spelke (1991; also Soja, 1992) proposed that children’s extensions of new words for solid objects are guided by a constraint to extend words to referents of the *same object kind* (e.g., extend the word “shoe” to other objects of the same kind – other shoes).

Landau, Smith, and Jones (1988) proposed a different formulation of these constraints. Instead of the whole object and taxonomic assumptions, they proposed that a *shape bias* guides children’s extensions of new words for solid objects. They argued that word extension is based on *shape*, rather than object kind per se, and that children depend on the shape of the original referent in extending novel words for solid objects (e.g., they extend the word “shoe” to other shoe-shaped entities).

A number of studies have demonstrated that children do in fact attend to shape in extending novel words for solid objects (e.g., Baldwin, 1989; Imai, Gentner, & Uchida, 1994; Jones, Smith, & Landau, 1991; Kim & Lee, 1996; Landau et al., 1992; Smith, Jones, & Landau, 1992; Smith & Jones, 1998). However, because shape is very often correlated with object kind membership (Baldwin, 1992), it is difficult to determine empirically whether children are guided by a “shape-as-cue” theory which involves constraints like the whole object and taxonomic assumptions in which shape serves as an indicator of object kind membership *or* a “brute shape” theory (Bloom, in press) which involves constraints like the shape bias in which shape per se is the underlying basis for word extensions. Nonetheless, it is clear that, in their extensions of novel words for solid objects, children typically depend on the perceptual property of shape.
Children do not, however, just learn words for solid objects: they also learn words for nonsolid substances like *juice, milk,* and *sand.* Acquiring words for nonsolid substances involves the same inductive problem that is involved in acquiring words for solid objects. For example, how does a child know that the word “*water*”, first applied to the stuff in a glass, also applies to the stuff in her bathtub, the stuff in the lake, and the stuff in puddles on the street, but not the stuff in Dad’s vodka tumbler?

It is not clear how the assumptions proposed to guide children’s acquisition of words for solid objects could also help them learn words for nonsolid substances. The same substance can occur in portions of varying shapes and sizes; therefore, paying attention to shape will not usually diagnose substance kind. Instead, other substance kind-relevant properties like colour, texture, and smell should be important. For example, water is the same substance whether it occurs as a drop, a cascade, or a lake, but a coloured, viscous, or odourous liquid is probably not water.

These considerations suggest that a different set of assumptions governs the acquisition of words for nonsolid substances. Soja et al. (1991) and Imai and Gentner (1997) (see also Hall, 1996) have shown that, in extending words for nonsolid substances, children and adults *do not* rely on shape as they do in extending words for solid objects. In these studies, 2-year-olds, 4-year-olds, and adults were taught novel words for solid objects and nonsolid substances and then asked to extend the novel words to one of two test items. In each pair of test items, one differed from the original in shape and the other differed in substance kind. For example, one of the standard items was a metal plumbing fixture shaped like a “*T*” and the two corresponding test items were a plastic “*T*” and a piece of metal. When the original referent was a solid object, participants respected shape and ignored
substance kind (i.e. chose the plastic "T"), but when extending words for nonsolid substances, they showed a greater tendency to ignore shape and to choose the items made of the same substance kind as the original.

On what basis did children extend words for nonsolid substances? Soja et al. proposed that children extend word meanings “from nonsolid substances to portions of substance of the same kind, *without yet having very good methods of determining kinds* [...] of substances” (Soja et al., 1991, p. 209). Adults are presumably better at determining what constitutes same substance kind, but the question of which perceptual properties signal same substance kind for adults and children has received little attention. The Soja et al. and the Imai and Gentner studies leave open the question of which *particular* properties adults and children attend to in making judgments about the extensions of words for nonsolid substances. In the nonsolid substance conditions of both sets of studies, the participants had to choose between substances that differed along a number of perceptual dimensions simultaneously. For example, one of the pairs of substances was Dippity-do and lumpy Nivea (a hand cream mixed with gravel). These substances differ in *texture, colour, and smell*: Dippity-do is a smooth, pink gel with a sweet odour, while the lumpy Nivea is a gritty, white cream with a flowery odour. One straightforward way to determine which of these properties serve(s) as a basis for adults’ and children’s word extensions is to isolate these properties by contrasting substances that differ along only one of these perceptual dimensions at a time.

In the Soja et al. and Imai and Gentner studies, children judged that substances that differed from an originally labeled referent *simultaneously* in colour, texture, and smell were not in the extension of a word for a nonsolid substance. Yet in their everyday lives, young children may use these properties *individually* to distinguish between substance kinds. For
example, they may use colour to distinguish between milk and apple juice; they may use
texture to distinguish between soft cotton sweaters and rough wool sweaters; and they may
use smell to distinguish between water and Mom’s perfume. It is therefore reasonable to
suspect that children can exploit these properties individually in making decisions about the
extension of words for substances. In this research, we will examine the relevance of each of
these perceptual properties to children’s extensions of novel words for nonsolid substances
by pitting the properties one at a time against shape.

In trying to understand adults’ and children’s extensions of words for solids and
nonsolids, another factor to consider is the conceptual domain of a potential referent. Two
such domains that children encounter from early in life are the toy artifact domain and the
food domain. Consider solid objects first. In the toy domain, shape is a good index of object
kind membership; therefore, within this domain, extensions of words for solid objects may be
based on shape. For example, balls come in many different colours and textures, but in order
for an object to belong to the kind “ball”, it must be spherical. The reason for this is that toys
are usually artifacts produced with an intended function; in most cases, this function requires
a particular shape. For instance, balls are built to be thrown, caught, kicked, and bounced:
non-spherical objects tend to be ill-suited to these functions and are rarely classified as
“balls”.

In contrast, within the domain of food, word extensions for solids may be less likely
to be based on shape. Some solid items within the food domain may have characteristic
shapes (e.g., conical carrots and ovoid lemons), but with food items, words refer to substance
kind as well object kind. For example, “carrot” refers to the conical object, but it also refers
to the crunchy orange substance. For foods, then, shape may be less important as an index of
which objects belong in the extension of a word while properties like colour (e.g., orange for carrots; yellow for lemons), texture (e.g., crunchy for carrots; pulpy for lemons) and smell (e.g., earthy for carrots; tart for lemons) may be more important. The reason for this is that substance kind rather than object kind correlates with comestibility. Properties, like taste, smell, colour, and texture are better indicators than shape of whether an item can be eaten, and these properties may, therefore, be more relevant to extensions of words for solid objects in the food domain.

Consider now nonsolid substances. The perceptual properties relevant to extensions of words for nonsolid substances may also vary across domains. For example, colour may be less relevant to extensions of words for nonsolid substances in the toy domain than in the food domain. Toys like Play-doh come in different colours and so, for these, the same word can be extended across different-coloured portions. However, for foodstuffs, substances that differ in colour (e.g., milk and grape juice) are more likely to belong to different substance kinds and so the same word is less likely to be extended across different-coloured portions.

Empirical and anecdotal evidence supports the notion that the individual properties colour, texture, and smell are particularly important within the food domain for determining word extensions because they seem to play an important role in matters of preference and consumption. Consider the role of colour in food preferences: parents often report that their children refuse all foods of a particular colour (Macario, 1991). Walsh et al. (1990) have shown that preschoolers express food preferences based entirely on colour. Preschoolers have also been shown to believe that foods of a particular colour will have a corresponding flavour (Walford, 1980). In adults, judgments of palatability and freshness are influenced by colour (Trinkaus, 1995), as is the perception of taste (Hyman, 1983).
Texture also plays an important role in food preferences. Many food preferences are based entirely on texture: the nearly universal aversion to lima beans can be blamed on their unpleasant combination of mushiness and graininess. Imitation foods (e.g., fake crabmeat, tofu hotdogs) gain acceptability only when they “feel” as well as taste like their targets (Lyman, 1989). Although most North Americans try hard to reduce their consumption of dietary fat, most fail because, without fat, most foods lose their pleasant creamy textures (Capaldi & VandenBos, 1991). Tournier and Louis-Sylvestre (1991) have reported differences in the caloric intake of foods that are identical in all respects except texture, and Boylston et al. (1996) have shown that patients who are losing weight will increase their food consumption in response to changes in food texture.

Odour is arguably the most important property associated with food (Lyman, 1989): a number of studies have documented the importance of odour perception as a determinant of food consumption and appreciation (Ferris & Duffy, 1989; Griep et al, 1997; Murphy & Davidson, 1992). The link between food preferences and smell may, to some extent, be learned (Logue, 1991), but smell preferences, even those related to food preferences, emerge very early and have been documented in newborns (Mennella & Beauchamp, 1997; 1996).

The importance of colour, texture, and smell to food preferences and consumption could conceivably lead to a heightening of the relevance of these properties to word extensions for food items in comparison to items from other conceptual domains like toys; this effect has, in fact, been shown for colour in a nonlinguistic classification task. Macario (1991) studied the domains of food and toy artifacts, and found that 3- and 4-year-olds preferred to classify novel solid objects by shape when they were told that the items were something to play with. When they thought these same objects were something to eat,
however, they classified them by colour. Macario’s procedure involved a nonlinguistic classification task, but Baldwin (1989) showed that by age 3, children attend to shape and ignore colour whether the task involves naming or not. If changing the domain of unfamiliar solid objects from *toy artifact* to *food* drives 3-year-olds to attend to properties other than shape in *nonlinguistic* classification, it is possible that the same domain manipulation in a *linguistic* task would influence the way in which children extend novel words for solid objects. Preschoolers have been shown to be sensitive to domain cues in linguistic tasks involving contrasts between animate and inanimate domains (Jones, Smith, & Landau, 1991; Smith & Jones, 1998). When they think novel objects represent *animate* objects, 2- and 3-year-olds show a greater tendency to rely on texture in extending novel words, whereas when they think similar novel objects represent *inanimate* objects, they show a greater tendency to rely solely on shape.

The preceding evidence suggests that further investigation into preschoolers’ understanding of domain cues is warranted. Specifically, do young children show different patterns of word extensions for solid objects described as *toy artifacts* and those described as *foods*? Are children’s extensions of words for nonsolid substances also sensitive to information about the domain of the referent? Which properties, besides colour, do young children attend to in extending words for *foods* (e.g., texture, smell)?

In sum, the following studies examined the relevance of the individual properties colour, texture, and smell (versus shape) to extensions of words for solid objects and nonsolid substances. Given the evidence that construals of novel words are, to some degree, dependent on the conceptual domain of the referent, this factor was incorporated into the experimental design. As well, in order to provide a direct comparison of the extension of
words for solids to that of nonsolids, both solid and nonsolid stimuli were used. Crucially, there were two matched sets of perceptually similar solid and nonsolid stimuli that contrasted only in solidity, enabling differences in word extension patterns across solids and nonsolids to be attributed to differences in solidity.

Experiment 1

The study involved a four-trial forced choice task modeled on the Soja et al. (1991) procedure. In this task, participants were taught a novel word for an unfamiliar item (the standard) and then asked to extend this word to one of two test items in each trial. Each pair of test items included one item that matched the standard in colour, texture, and smell but differed from it in shape, and a second that matched the standard in shape but had a different colour, texture, or smell. For any particular participant, the same property (i.e., colour, texture, or smell) was manipulated across each of the four trials.

Soja et al. (1991) found that for solid objects, word extensions were based on shape, but that for nonsolid substances, they were based on some combination of colour, texture, and smell rather than shape. Word extensions were never based on shape and colour, texture, and smell, and so we felt justified in pitting shape against each of the proposed substance kind-relevant properties in the forced choice procedure. When a participant chose the shape match, they appeared to extend the novel word based on shape, implying that the other properties were less important to the extension of the novel word. Contrarily, when a participant did not choose the shape match, they appeared to treat one of the properties colour, texture, or smell as more relevant than shape in extending the novel word.

The perceptual properties that adults find relevant to their extensions of words for nonsolid substances have never been individually examined. Before investigating children's
extensions of words for nonsolid substances, we wanted to establish whether adults attend to the proposed substance-relevant properties (colour, texture, smell). Similarly, little, if any, research has investigated adults’ word extensions across different conceptual domains.

Before investigating children’s attention to domain cues, we wanted to determine whether adults’ word extensions are sensitive to this type of information. Therefore, in Experiment 1, adults were questioned about their extensions of words for nonsolid substances and solid objects across the domains of food and toy artifacts.

Method

Participants

One hundred and twenty adults (age range: 17-30 years) took part. They were undergraduate psychology students who received course credit for their participation. Participants were tested in small groups (2-3 participants at a time) in the laboratory. Thirty participants were randomly assigned to each of four conditions defined by Solidity (solid, nonsolid) and Domain (toy, food): Solid-Toy, Solid-Food, Nonsolid-Toy, and Nonsolid-Food. Within each of these four conditions, ten participants were assigned to the Colour condition, ten were assigned to the Texture condition and ten were assigned to the Smell condition.

Stimuli

There were two solid stimulus sets (A and B solid) and two matching nonsolid sets (A and B nonsolid) used in both the Toy conditions and the Food conditions. Each participant saw either the solid sets or the nonsolid sets. The matching solid and nonsolid stimulus sets were designed to be as perceptually similar as possible, such that matching pairs of stimuli from solid set A and nonsolid set A contrasted only in solidity (the same was true for solid set
B and nonsolid set B). For stimulus sets A, the solids were made of plaster of paris, and the nonsolids were made of icing; for stimulus sets B, the solids were made of wax, and the nonsolids were made of Vaseline. Each set consisted of nine items: the standard and eight test items. Two test items differed from the standard in shape, two differed in colour, two differed in smell, and two differed in texture. See Figure 1 for details of the complete stimulus sets. A hand puppet was used to introduce the stimuli and to ask the questions.

Procedure

Participants were first given a brief explanation of the task. They were told that they would be introduced to an item and taught a word for it but would not be given any further information about the meaning of the word. They were then told that they would be shown pairs of items on plates and should choose one member of each pair and note their choice on the provided answer sheets.

Each participant received four trials: two trials from stimulus set A and two from stimulus set B (either solid or nonsolid). The trials were blocked by stimulus set: both trials from one stimulus set were given before moving on to the second set. The order of presentation of the stimulus sets was counterbalanced across participants, and the side of presentation of test items was counterbalanced across trials.

The experimenter (either the author or an undergraduate student trained by the author) began by telling the participants that her puppet would be talking to them about what he liked to “play with” (Toy condition) or “eat” (Food condition). They were told that the puppet was then going to ask them some questions and that they would have to show the puppet what else he liked to eat or play with. The experimenter then brought out one of the standards and the puppet examined it by looking at it (i.e., highlighting visible properties like colour),
touching it (i.e., highlighting texture), and smelling it (i.e., highlighting smell). The puppet then introduced the standard, saying, for example, “This is my dax.” In the Toy condition he added, “I like to play with it”; and in the Food condition he added, “I like to eat it.” The puppet repeated the introduction before bringing out two test items.

In each of the four trials, one of the test items differed from the standard in shape, but was identical in all other respects (same-substance test item), and the second differed from the standard in colour, texture, or smell, but had the same shape (same-shape test item). The puppet looked at each of the test items and highlighted the ways in which they differed from the standard (e.g., for a trial in the Smell condition, he said: “This has a different smell than this” for the same-shape item, and he said “This has a different shape than this” for the same-substance item) and then said: “Which of these is the dax?”

**Results**

The first analyses focused on the mean percentage of same-shape choices. A preliminary analysis with paired samples t-tests showed that the mean percentage of same-shape choices for stimulus sets A and B did not differ significantly, t (59) = 1.15, p = .26 (solids), t (59) = 1.14, p = .26 (nonsolids). On that basis, the trials from the two stimulus sets were combined for all further analyses.

Based on the results from Soja et al. (1991) and Macario (1991), we predicted that there would be more same-shape choices in the Solid than in the Nonsolid conditions and more same-shape choices in the Toy than in the Food conditions. The mean percentages of same-shape choices in each condition are shown in Table 1. These numbers were submitted to a 2 (Solidity: Solid, Nonsolid) by 2 (Domain: Toy, Food) by 3 (Property: Colour, Texture, Smell) between-subjects ANOVA. As predicted, there was a main effect of Solidity, F (1,
indicating more same-shape choices in the Solid than in the Nonsolid conditions. There was also a main effect of Domain, $F(1, 108) = 5.5$, $p = .021$, indicating more same-shape choices in the Toy than in the Food conditions. Solidity and Domain did not interact significantly, suggesting that the effects of Domain and Solidity contributed independently to the tendency to extend words on the basis of shape: shape was more relevant to extensions of words for solid objects than for nonsolid substances in both the toy domain and the food domain.

There was no main effect of Property, indicating that the percentage of same-shape choices did not differ when the contrasting property was either colour, texture, or smell. In addition, the interaction between Property and Domain was not significant, $F(2, 108) = 1.10$, $p = .34$. This result suggests that the effect of Domain was equivalent in the three different Property conditions. However, the ANOVA revealed a significant interaction between Property and Solidity, $F(2, 108) = 4.88$, $p = .009$. This interaction reflected differences in the strength of the solidity effect in the three different Property conditions. Tests of simple effects showed that there were significant effects of Solidity in both the Colour, $F(1, 108) = 33.1$, $p < .001$, and the Smell conditions, $F(1, 108) = 4.33$, $p = .040$. However, in the Texture condition, the Solidity effect was in the predicted direction, but failed to reach conventional levels of significance, $F(1, 108) = 3.18$, $p = .077$. No other effects in the ANOVA were significant.

We next compared the mean percentage of same-shape choices to levels expected by chance (i.e., 50%) within each of the four conditions (Solid-Toy, Solid-Food, Nonsolid-Toy, Nonsolid-Food) using t-tests. The percentage of same-shape choices was above chance in the Solid-Toy condition, $t(29) = 5.0$, $p < .001$, and it was above 50% in the Solid-Food
condition, but not significantly, \( t(29) = 1.9, p = .068 \). The percentage of same-shape choices was at chance in the Nonsolid-Toy condition, \( t(29) = -1.0, p = .316 \), and it was below chance in the Nonsolid-Food condition, \( t(29) = -3.5, p = .001 \). These effects are illustrated in Figure 2.

Our second analyses explored participants' overall *patterns* of selections across the four trials. Any participant who chose the same-shape test item three or four times (out of four) was classified as showing a *shape* pattern; any participant who chose the same-substance test item (i.e., the one that matched the standard in colour, texture, and smell) three or four times (out of four) was classified as showing a *substance* pattern. Participants who chose the same-shape test item on two trials and the same-substance test item on the other two trials were assigned to the *no pattern* category and were excluded from this analysis.

Figure 3 shows the number of participants classified as showing shape patterns in each condition. These numbers provide information about the consistency of individual participants' performance across the four trials. Chi-square analyses of the numbers of shape and substance patterns yielded results similar to the results of the ANOVA analyses of the percentage of same-shape choices. The number of shape patterns was significantly higher in the Solid than in the Nonsolid conditions, \( \chi^2(1, N = 112) = 22.3, p < .001 \). This number was also higher in the Toy than in the Food conditions, \( \chi^2(1, N = 112) = 4.4, p = .036 \). These results show that the Solidity and Domain effects in the preceding analyses reflect consistent within-participant patterns of selection.

In sum, the results suggest that, in extending words for solid objects, adults were more willing to extend novel words to items sharing the same shape as the original referent (but differing in colour, texture, or smell) than they were in extending words for nonsolid
In this study, adult participants attended more to shape in extending words for solid objects than in extending words for perceptually similar nonsolid substances. The response patterns indicate that the perceptual properties colour and smell (and to a lesser extent, texture) were more relevant to the extensions of novel words for nonsolid substances than they were to the extensions of words for solid objects. This is a new finding, because previous studies that have found an effect of solidity (e.g., Imai & Gentner, 1997; Soja, 1992; Soja et al., 1991) have not allowed for evaluations of the relevance of individual substance kind-relevant properties.

In addition, the conceptual domain of the stimulus had an independent impact on the perceptual properties seen as relevant to the extensions of novel words for both solid objects and nonsolid substances. Specifically, adults treated the perceptual properties colour, texture, and smell as more relevant to the extensions of novel words for items in the domain of food than to the extensions of words for items in the domain of toy artifacts. This result reflects the effect of an entirely conceptual factor: participants saw the same stimuli, labeled in
exactly the same way, but their construals of the labels were influenced by hearing the stimuli described as belonging to different domains. Differing construals led participants to rely on different properties in their word extension judgments. This result provides an extension of Macario’s (1991) finding with preschoolers that the properties relevant to classification (colour or shape) depend on conceptual domain. Importantly, these results show, for the first time, that the domains of *toy artifacts* and *food* are relevant not only in nonlinguistic classification tasks, but also in adults’ judgments of novel word extensions involving both *solid objects and nonsolid substances*, and involving *smell and texture* as well as colour.

One point worthy of further discussion concerns the observed interaction between Property and Solidity. An investigation of this interaction revealed that adults showed a weaker Solidity effect in the Texture condition than in either the Colour or Smell conditions. Adults were less likely to choose the same-substance test items in extending words for nonsolid substances when texture was pitted against shape than when colour or smell was pitted against shape. We propose two possible reasons to explain why adults did not make more same-substance choices in extending words for nonsolid substances when shape and texture were contrasted.

One possibility is that, when it does not correlate with other properties, texture on its own is not a very good guide to substance kind membership. If this is true, then participants may be more willing to rely on texture in their word extensions if the texture changes are accompanied by changes in a second property. One way of testing this possibility would involve combining texture with a second property (e.g., colour) in order to determine if
texture in conjunction with other properties is a stronger indicator of substance kind membership.

Alternatively, it is possible that, although texture does serve as a good guide to substance kind membership, changes in texture are most often accompanied by changes in other properties (e.g., colour or opacity) and our unidimensional texture change was, therefore, not convincing. A related possibility involves the difficulty of manipulating texture by itself. A change in texture very often signals a change in substance kind, which, conversely, makes it very difficult to alter texture without altering the substance or any of its other properties, as was required by the experimental manipulation. The particular manipulation involved embedding small beads in the stimuli, thus changing the surface smoothness. Texture is, however, a broadly encompassing property and includes many facets other than surface smoothness: viscosity, coarseness, flexibility, rigidity, graininess, cohesiveness, etc. It is possible that changing the surface texture of the stimuli did not constitute a sufficiently convincing alteration of that particular property, or that simply seeing and hearing about a texture change was not salient enough: impressions of most textures depend primarily on tactile sensations (Lyman, 1989) and participants were discouraged from touching the stimuli.

Given these considerations, it is possible that participants did not believe that the test items with beads embedded in them truly had different textures than the standard items they were compared with. The participants may simply have construed them as the same substance (with the same texture) with beads added. Participants may have come to this conclusion because they first saw the novel substance without the beads. If they had only seen the novel substance with beads, they may have been more willing to see the beads as an
integral part of the substance; that is, they may have perceived the substance as having a particular "bumpy" surface texture. This could be addressed in future work by embedding beads in the standards and same-substance items. If the standard had a rough surface texture (i.e., if it had beads embedded in it), then participants might be more inclined to believe that this surface texture is relevant to extensions of words for this substance and that substances with different surface textures do not belong in the extension of the same word. We are currently planning follow up studies to further explore this issue.

Experiment 2

Experiment 2 was a replication of Experiment 1 conducted with 3-year-olds in order to determine whether young children’s word extension judgments reflect a sensitivity to the same factors as those of adults. Children as young as two years have shown an ability to distinguish between solids and nonsolids in their word extensions (Imai & Gentner, 1997; Soja et al., 1991; Soja, 1992), and to distinguish between objects from different conceptual domains (Jones, Smith, & Landau, 1991; Smith & Jones, 1998). However, three years is the youngest age at which children have been shown to distinguish between the domains of toy artifacts and food (Macario, 1991). Because these were the domains of interest in the current study, we chose to study 3-year-olds.

Method

Participants

One hundred and twenty 3-year-olds participated in the study. Thirty children were randomly assigned to each of four conditions: Solid-Toy (M = 3;6; SD = 3.0 months; range = 3;0-3;11; 15 boys and 15 girls), Solid-Food (M = 3;6; SD = 3.1 months; range = 3;1-3;11; 13 boys and 17 girls), Nonsolid-Toy (M = 3;7; SD = 2.8 months; range = 3;0-3;11; 17 boys and
13 girls), Nonsolid-Food (M = 3.6; SD = 3.6 months; range = 2.11-3.11; 15 boys and 15 girls). Within each condition, 10 children were randomly assigned to each of the three property conditions (Colour, Texture, Smell).

Most of the children were recruited through local preschools and daycares and were tested individually in their classrooms or in an adjoining room during regular school hours. The remaining children were recruited through public notices and were tested in the laboratory. The children received stickers or Play-doh for their participation; parents who brought their children to the lab were reimbursed for parking expenses.

Stimuli

The stimuli were identical to those used in Experiment 1.

Procedure

The procedure was identical to the one followed in Experiment 1, with the following exceptions. First, the children were not given the initial explanation about learning a new word; instead, the procedure began directly with the puppet telling them he was going to talk to them about what he liked to eat (Food condition) or play with (Toy condition). Second, the children were asked to repeat the novel words after the puppet introduced the stimuli. Third, instead of writing down their answers, the children were asked to indicate their choices to the experimenter.

Results

As in Experiment 1, we focused first on the mean percentage of same-shape choices. Preliminary analyses with paired samples t-tests showed that the mean percentage of same-shape choices for stimulus sets A and B did not differ significantly, $t (59) = .77, p = .44$ (solids), $t (59) = 1.53, p = .13$ (nonsolids). On that basis, the trials from stimulus sets A and B
were combined for all further analyses. As well, in a 2x2x2x3 ANOVA involving Sex, Solidity, Domain, and Property, there were no significant main effects or interactions involving sex; therefore, responses from boys and girls were combined in all subsequent analyses.

Based on Soja et al. (1991) and Macario (1991), we predicted that there would be more same-shape choices in the Solid than in the Nonsolid conditions and more same-shape choices in the Toy than in the Food conditions. The mean percentages of same-shape choices in each condition appear in Table 2. These numbers were submitted to a 2 (Solidity: Solid, Nonsolid) by 2 (Domain: Toy, Food) by 3 (Property: Colour, Texture, Smell) between-subjects ANOVA. As with the adults, there was a main effect of Solidity, $F(1, 108) = 13.9, p < .001$, indicating more same-shape choices in the Solid than in the Nonsolid conditions. Like the adults, there was also a main effect of Domain, $F(1, 108) = 3.9, p < .05$, indicating more same-shape choices in the Toy than in the Food conditions. Also like the adults, Solidity and Domain did not interact significantly, suggesting that the effects of Domain and Solidity contributed independently to the tendency to extend words on the basis of shape: shape was more relevant to 3-year-olds’ extensions of words for solids than for nonsolids in both the toy domain and the food domain.

As in Experiment 1, there was also no main effect of Property, indicating that overall, the percentage of same-shape choices did not differ when the contrasting property was either colour, texture, or smell. In addition, the interaction between Property and Domain was not significant, $F(2, 108) = 1.75, p = .18$. This result suggests that the effect of Domain was equivalent in the three Property conditions. However, also like adults, the ANOVA revealed a significant interaction between Property and Solidity, $F(2, 108) = 4.81, p = .01$. As it did
with adults, the solidity effect differed across the three properties. With adults, the solidity effect was weakest in the Texture condition; however, for 3-year-olds the solidity effect was weakest in the Colour condition. Tests of simple effects reveal that the Solidity effect was significant in the Texture, \( F(1, 108) = 7.57, p = .007 \), and the Smell conditions, \( F(1, 108) = 15.91, p < .001 \), but not in the Colour condition, \( F(1, 108) = .08, p = .78 \). No other effects in the ANOVA were significant.

We next compared the mean percentage of same-shape choices to levels expected by chance (i.e., 50%) within each of the four conditions (Solid-Toy, Solid-Food, Nonsolid-Toy, Nonsolid-Food). The results were similar to those obtained with adults. The percentage of same-shape choices was above chance in the Solid-Toy condition, \( t(29) = 5.3, p < .001 \); in the Solid-Food condition, it was above 50% but not significantly, \( t(29) = 1.9, p = .062 \). The percentage of same-shape choices was at chance in the Nonsolid-Toy, \( t(29) = .31, p = .758 \) condition, and, like the adults, 3-year-olds in the Nonsolid-Food condition chose the same-shape test item less than 50% of the time, but this percentage was not significantly less than chance, \( t(29) = -.342, p = .662 \). These results are shown in Figure 4.

Our second analyses explored the consistency of the children’s responses across trials. We categorized their overall patterns of selections exactly as we did with adults: any child who chose the same-shape test item three or four times (out of four) was classified as showing a shape pattern; any child who chose the same-substance test item three or four times (out of four) was classified as showing a substance pattern. Children who chose the same-shape test item on two trials and the same-substance test item on the other two trials were categorized as showing no pattern and were excluded from this analysis.
Figure 5 shows the number of 3-year-olds categorized as showing shape patterns in each condition. Chi-square analyses of the numbers of shape and substance patterns showed that the number of shape patterns was significantly higher in the Solid than in the Nonsolid conditions, $\chi^2(1, N = 89) = 7.98$, $p = .005$, but while there was a higher number of shape patterns in the Toy than in the Food condition, this effect failed to reach significance, $\chi^2(1, N = 89) = 2.12$, $p = .15$. These results suggest that, while 3-year-olds as a group showed a sensitivity to the information provided about the referents’ conceptual domain (based on the previous analyses), individual 3-year-olds did not show consistent selection patterns reflective of this sensitivity.

In sum, the results suggest that 3-year-olds were more likely to attend to shape in extending novel words for solid objects than they were in extending words for nonsolid substances. Their extensions of novel words were also affected by the conceptual domain of the referent: 3-year-olds attended significantly more to shape in extending words for both solid objects and nonsolid substances when they were told the referent belonged to the toy domain than when they were told it belonged to the food domain. Overall, preschoolers tended to pick the same-shape item equally often regardless of the contrasting substance kind-relevant property. However, children’s tendency to pick the same-shape item more often for solid objects than for nonsolid substances differed according to the contrasting property. Specifically, this effect of the referent’s solidity was significant when the property was smell or texture, but not when it was colour.

**Discussion**

As with the adults in Experiment 1, the results with 3-year-olds replicate and extend the results of previous studies (e.g., Hall, 1996; Imai & Gentner, 1997; Soja et al., 1991;
Soja, 1992), showing that children attend more to shape in extending words for solid objects than for nonsolid substances. Previous studies that have found an effect of solidity (e.g., Imai & Gentner, 1997; Soja, 1992; Soja et al., 1991) have not considered the relevance of the individual properties that contrasted with shape. We have shown that this solidity effect obtains when the contrasting property is either texture or smell but, surprisingly, not when it is colour.

The results also demonstrate a significant effect of the conceptual domain of the referent on children’s word extension judgments. Specifically, preschoolers attend more to the properties colour, texture, and smell in extending words for both solids and nonsolids when they are told the referent of a novel word belongs to the conceptual domain food than when they are told it belongs to the domain of toy artifacts. This result reflects the effect of an entirely conceptual factor: 3-year-olds saw the same stimuli, labeled in exactly the same way, but their construals of the labels were influenced by hearing the stimuli described as belonging to different domains. These results extend Macario’s (1991) finding that the properties relevant to classification (colour or shape) depend on conceptual domain. Importantly, these results show, for the first time, that the domains of toy artifacts and food are relevant not only in nonlinguistic classification tasks, but also in preschoolers’ judgments of novel word extensions involving both solid objects and nonsolid substances, and involving smell and texture as well as colour.

One point worthy of further discussion concerns the observed interaction between Property and Solidity. An investigation of this interaction revealed that 3-year-olds’ word extension judgments were influenced by the solidity of the referent when the property contrasted with shape was texture or smell but not when it was colour. Given that adults in
Experiment 1 did show a solidity effect when colour was contrasted with shape, we wondered why 3-year-olds failed to show such an effect in Experiment 2. We propose two possibilities. The first is that the 3-year-olds may not have thought that word extensions for nonsolid substances should be based on colour (i.e., they may have thought that changes in colour do not signal changes in substance kind).

Alternatively, the 3-year-olds’ failure to attend to colour in extending words for nonsolid substances may be attributable to methodological factors. For the participants in the Colour condition, the same-shape item was a different bright colour (red, yellow, green, or orange) for each trial, while the same-substance item was always white. The 3-year-olds were strongly drawn to the coloured stimuli, often trying to touch them and almost invariably commenting on them (e.g., “It’s green!” “That’s the most beautiful one”), while the children in the Texture and Smell conditions seemed much less impressed with the test items. The children in the Colour condition may have chosen the brightly coloured same-shape test items because they were so much more interesting than the white same-substance test items, rather than because they thought the novel words should be extended on the basis of shape: preschoolers prefer strong, bright colours (Lyman, 1989) and red, yellow, green, and orange are among their favourites (Dember & Warm, 1979).

We are currently conducting a follow-up study designed to determine whether this methodological consideration may explain the differences between adults’ and 3-year-olds’ word extension judgments. In this study, we have equated the perceptual salience of the same-shape test items with the standard and same-substance test items by using bright colours for all the items. For example, in one trial, the standard and same-substance items are orange and the same-shape test item is yellow. The children in the follow-up study are
showing a Solidity effect, suggesting that children do believe that a change in colour signals a change in substance kind and that, in Experiment 2, their word extension judgments were influenced by the perceptual salience of the test items.

Experiments 1 and 2: Effects of Age

In order to compare responses from adults and 3-year-olds more directly, the results from Experiments 1 and 2 were combined and submitted to a 4-way ANOVA with Age (adult, 3-year-old) as a fourth 2-level between-subjects factor. In this analysis, we focussed only on effects involving Age. There was no significant main effect of Age, indicating that adults and preschoolers overall showed similar tendencies to extend the novel words to the same-shape items. However, the analysis revealed a significant 2-way interaction between Solidity and Age, F (2, 216) = 5.39, p = .021, and a significant 3-way interaction involving Solidity, Property, and Age, F (2, 216) = 9.17, p < .001. Because in Experiments 1 and 2, adults and 3-year-olds showed distinctive Property by Solidity interactions, these results were not unexpected. We tested the simple effects of Solidity in the three Property conditions for both age groups and found that adults showed a very strong solidity effect in the Colour condition, F (1, 216) = 43.5, p < .001, while 3-year-olds failed to show a significant effect of solidity in the same condition, F(1, 216) = .052, p = .82. In the Texture and Smell conditions, the Solidity effect was significant for both adults and 3-year-olds. No other interactions involving Age were significant.

In sum, adults and 3-year-olds made very similar word extension judgments in these studies. They did, however, differ significantly in their word extensions involving the property colour. As mentioned in the discussion of the preceding experiment, we are currently investigating the reasons behind this difference.
General Discussion

Recent word-learning studies have shown that young children attend to different properties in making judgements about the extensions of novel words for solid objects and nonsolid substances (e.g., Hall, 1996; Imai & Gentner, 1997; Soja, 1992; Soja et al., 1991). Results from other studies have shown that young children attend to different properties in categorizing and extending novel words for solid objects described as belonging to different domains (e.g., Jones et al., 1991; Macario, 1991; Smith & Jones, 1998). The experiments in this paper extend this research by comparing extensions of novel words for solid objects and perceptually similar nonsolid substances, by examining adults’ and children’s sensitivity to domain cues in their extensions of words for both solid objects and nonsolid substances, and by isolating particular perceptual properties and examining their relevance to extensions of novel words for solid objects and nonsolid substances.

In Experiment 1, we found that shape was more relevant to adults’ extensions of words for solid objects than to their extensions of words for nonsolid substances. We found that shape was also more relevant to their extensions of words for items in the toy domain than for items in the food domain. We also found that the effect of the referent’s solidity differed depending on the property that was contrasted with shape. Specifically, this effect was stronger when the contrasting property was colour or smell than when it was texture. In Experiment 2, we found that 3-year-olds’ word extension patterns were similar to those of adults for both solids compared to nonsolids and toy artifacts compared to foods. We again found that the effect of the referent’s solidity varied according to the property that was contrasted with shape. Whereas this effect was strong when the property was texture or smell, it was nonexistent when the property was colour. As previously discussed, we are
currently investigating the possibility that this lack of effect involving colour is attributable to methodological issues.

An issue worth considering is how these results bear on conclusions drawn from previous word extension studies. Numerous studies have consistently found that children (and adults) extend words for solid objects on the basis of shape (e.g., Baldwin, 1989; Imai, Gentner, & Uchida, 1994; Jones, Smith, & Landau, 1991; Kim & Lee, 1996; Landau et al., 1992; Smith, Jones, & Landau, 1992; Smith & Jones, 1998). However, our results showed that adults and preschoolers did not reliably attend to shape in extending novel words for solid objects when they were guided to construe these objects as belonging to the food domain. Either of two competing conclusions can be drawn from this result depending on participants’ interpretations of the novel words.

One possibility is that participants interpreted the words for solid objects described as food as naming the referent’s *object kind* (or category). These results would thus suggest that properties other than shape are relevant to determining object kind membership for solid objects in the food domain. This conclusion would be inconsistent with the Landau et al. shape bias proposal which suggests that “children interpret novel count nouns in the context of novel objects as referring to an object category *organized primarily by object shape* [italics added]” (Landau, Jones, & Smith, 1992, p. 88).

Alternatively, participants may have interpreted the words for solid objects described as belonging to the food domain as naming the referent’s *substance kind* (or category). In this case, the results would not be inconsistent with the shape bias proposal, because that proposal applies only to words referring to object kinds (i.e., count nouns). However, if participants did interpret the novel words for solid foods as referring to substance kinds, then these results
would complicate the Soja et al. (1991) proposal that all words for solid objects should be extended on the basis of object kind, and all words for nonsolid substances should be extended on the basis of substance kind. If our participants interpreted novel words for solid food objects as referring to substance kind, then at least some words for solid objects must be extended on the basis of substance kind rather than object kind.

How could we determine which of these conclusions is justified? One approach would be to manipulate the syntactic information that accompanies the novel words. In the current studies, participants were not given any syntactic information to guide their interpretations of the novel words: the syntactic frame we used (e.g. "This is my dax") was consistent with interpreting the words as referring to object kinds or substance kinds. However, participants' interpretations of the novel words could be influenced by providing syntactic information specific to object or substance kind interpretations. For example, discrete quantifiers like "a" can only be used with count nouns, which typically refer to object kinds; continuous quantifiers like "some" can only be used with mass nouns, which typically refer to substance kinds. If discrete quantifiers were used in introducing novel words for solid objects (e.g., "This is a dax"), we could expect participants to interpret the novel words as count nouns referring to object kind. Similarly, if continuous quantifiers were used in introducing novel words for nonsolid substances, (e.g., "This is some dax"), we could expect participants to interpret the novel words as mass nouns referring to substance kind.

If participants in the current studies interpreted words for solid objects from the food domain as mass nouns referring to substance kind, then we should expect to see a different pattern of results when participants are specifically guided to interpret words for solid objects as count nouns: participants should attend to shape in extending all words for solid objects
regardless of whether the objects are described as belonging to the toy domain or the food domain. Alternatively, if participants in the current studies interpreted words for solid objects from the food domain as *count* nouns referring to object kind, then we should expect to see the *same* pattern of results when participants are specifically guided to interpret words for solid objects as *count* nouns: participants should attend to shape in extending words for solid objects described as belonging to the toy domain but not for solid objects described as belonging to the food domain. Thus, interpretations of the results from the current studies could be clarified by guiding participants in future studies to make specific interpretations of the *count/mass* status of novel words.

The fact that further studies will be required to address the previous issue should not diminish the contributions of this work. We have shown that adults and children attend to shape in extending words for solid objects more often than in extending words for nonsolid substances. Importantly, we have demonstrated this effect by pitting shape against *individual* substance kind-relevant properties. We have also shown that conceptual domain is an important factor in judgments of word extensions. Specifically, we have shown for the first time that adults and 3-year-olds attend to different properties in making judgments of word extensions for the same items described as belonging to either the toy artifact domain or the food domain. We have further shown that this domain effect applies to both solid objects and nonsolid substances and is consistent across the properties colour, texture, and smell.

These studies contribute to word-learning theory by documenting the richness of children's understanding of the factors relevant to word meaning. We have shown that, by the time they are three, children are able to draw from several sources of information in making judgments about the extension of a novel word. They are able to combine their
understanding of the information provided by the ontological status of a referent (i.e.,
whether it is solid or nonsolid) with their understanding of the information provided by
domain cues to inform their decisions about the relative importance of various perceptual
properties.
References


Table 1
Mean Percentage of Same-Shape Choices for Adults (Experiment 1)

<table>
<thead>
<tr>
<th></th>
<th>Solid</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Toy</td>
<td>Food</td>
<td>Toy</td>
<td>Food</td>
<td></td>
<td></td>
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<tr>
<td>Texture</td>
<td>72.5</td>
<td>60</td>
<td>42.5</td>
<td>45</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Colour</td>
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<td>25</td>
<td>12.5</td>
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<td></td>
<td></td>
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<tr>
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<td>75</td>
<td>52.5</td>
<td>57.5</td>
<td>17.5</td>
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</tr>
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</table>
Table 2

Number of Same-Shape Choices for 3-year-olds (Experiment 2)

<table>
<thead>
<tr>
<th></th>
<th>Solid Toy</th>
<th>Solid Food</th>
<th>Nonsolid Toy</th>
<th>Nonsolid Food</th>
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</thead>
<tbody>
<tr>
<td>Texture</td>
<td>72.5</td>
<td>72.5</td>
<td>42.5</td>
<td>50</td>
</tr>
<tr>
<td>Smell</td>
<td>82.5</td>
<td>60</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>Colour</td>
<td>77.5</td>
<td>52.5</td>
<td>67.5</td>
<td>67.5</td>
</tr>
</tbody>
</table>
Stimulus sets A
Solid: Plaster of paris
Nonsolid: Icing

Stimulus sets B
Solid: Wax
Nonsolid: Vaseline

Standard items:

Same-substance test items:

Same-shape test items:

Colour condition

Texture condition

Smell condition

vanilla
eucalyptus

vanilla
eucalyptus