Psychology of Language and Communication 2004, Vol. 8, No. 1

MACIEJ HAMAN
University of Warsaw

REACTION TIME STUDY OF SHAPE AND TEXTURE BIAS IN PRESCHOOLERS' NAMING

Two reaction time experiments were designed to test a conceptual explanation of shape and texture biases in young children's naming processes against the Smith et al. (1996) "dumb attentional mechanism" and the Imai et al. (1994) hypotheses. We assumed that (1) if shape-biased and category-based naming are based on the same processes no substantial time differences will be expected between them, and that (2) if perceptual biases have conceptual bases, systematic differences in reaction times and bias distribution should be found between different conceptual categories. Although in both experiments reaction times for biased choices were a little quicker than for category-based choices, the difference was too small to be attributed to substantially different cognitive mechanisms (conceptual vs. perceptual processing). Texture bias for inanimate natural kinds was also found in both experiments. Texture bias has conceptual bases and reflects the importance of substance for inanimate natural kind categories. Finally, in experiment 2., when no forced selection procedure was used, a within-category texture-different alternative was selected much more often than either cross-category (shape and texture biased), or within-category shape-biased alternatives. Shape indicates important causal properties of objects, so children rather tend to reject shape-different exemplars than extend new names onto shape-similar objects from a different category.

Introduction

The problem of young children's processes of naming is among the crucial issues of language acquisition (see e.g. Bloom, 2002; Gleitman & Landau, 1994; Macnamara, 1982; Smith, 2001). Are there early semantic or formal constraints on naming, or are strategies of naming more or less sophisticated statistical generalizations of children's experiences with objects and names accumulated in the first few years? One of the most prominent solutions following the statistical generalization is the hypothesis of *shape bias* proposed by Landau, Smith, & Jones (1988) and later developed in subsequent studies (e.g. Smith, Jones & Landau, 1996; Smith, 2001). These authors aimed originally to find a psychological solution for Quine's question what part of the per-

* Address for correspondence: Maciej Haman, Faculty of Psychology, University of Warsaw, Stawki 5/7, 00-183 Warszawa, Poland. E-mail: meh@engram.psych.uw.edu.pl

ceptual experience should be associated with the new word uttered simultaneously by other participants in the situation (like the situation of the child learning a new word). Quine claimed that any abstract semantic or ontological distinction could only be acquired from the linguistic environment, so the meaning of the first words should be constrained perceptually. As noted by Landau, Smith & Jones (see Smith et al., 1996; Smith, 2001), most of the first few dozens of words learned by children are names for solid objects, and shape (silhouette) is their most salient property, so after learning about fifty words, children develop a "dumb" (Smith et al. 1996) perceptual-attentional mechanisms that link the word with the object's shape and allow for extension of the word's meaning onto shape-similar objects. As the child's naming experience grows, alternative, more specific and subtle strategies are acquired, so that in adults the shape bias is restricted only to simple, unknown artifacts. For example, about the age of three children learn to attend more to texture when the object has eyes (Jones, Smith & Landau, 1991) or shoes (Jones & Smith, 1998). This is however an attentional strategy based on empirical correlation between shoes or eyes and specific kinds of texture, rather than on an abstract ontological category of *animacy*. Categories like *living thing* or *substance* are social/cultural constructions that could be transmitted to the child through the linguistic system (e.g. English count/mass syntax for the substance category).

The evidence for the Landau, Smith & Jones hypothesis comes mainly from the name-extension tasks compared to no-name conditions. Typically, a standard object, made of a common material (e.g. wood, or wire, or nonsolid substance like clay) was presented in the context of a pseudo word (e.g. "this is a dax"). Then some test objects were shown. The test objects differed from the standard on dimensions of shape, texture, size, color, or substance. Children were then asked to choose another "dax". As reported by Landau et al. (1988), in the case of solid objects, two- and three-year-olds selected mostly by shape, ignoring even apparent differences on other perceptual dimensions. However, when asked to choose "one alike", subjects' decisions were based on overall similarity rather than any isolated property. A reservation could be made that objects used in these studies were usually simple artifacts and were not similar to any objects known to children, so such a situation did not provide enough information to enable subjects to use their semantic knowledge to accomplish the task (if they had any general semantic knowledge). This reservation does not, however, apply to the work of Imai, Gentner and Uchida (1994).

In the Imai et al. (1994) study, three- to six-year-old children and a group of adults were asked to extend the "dinosaur language word" from the standard onto one of three test alternatives: taxonomic, thematic, and shape-similar. For example, if the standard was a picture of a birthday cake, the taxonomic alternative was another cake, thematic alternative was some birthday-party stuff, and shape alternative was a hat. Preschoolers made significantly more shape-based choices (about 50%) than either taxonomic or thematic ones, although there was a developmental tendency decreasing the shape bias. Adults were not biased. However, in the no-naming task, when asked to find the object "going-with" the standard, children usually picked a thematic alternative. Imai et al.'s explanation of these results is similar to that of Landau, Smith and

Jones, although they talk about "children's theory of naming", instead of "dumb attentional mechanism" (Smith et al., 1996). This "theory" seems however to be perceptually, not conceptually, based. What is interesting here is that although Imai et al. explored object categories well known to children, they found shape bias in subjects considerably older than those investigated in the Landau, Smith & Jones experiments. In a subsequent study, Gentner & Namy (1999) found some conditions in which shape bias is overridden by taxonomic relations in the Imai et al. (1994) procedure. This happens when two objects from the same taxonomic category (either identical or different) are set together. According to Gentner and Namy, if the child is given the possibility to compare the category instances, it becomes more likely that he/she would find higher-level structural similarity between them.

More reservations could, however, apply to both groups of shape bias studies described above. Firstly, there is evidence that young children use ontological categories of object and substance to make their early lexical decisions rather than learn them later through linguistic experience (e.g. picking out the count/mass noun syntactic distinction). This was demonstrated, for example, by Soja, Carey & Spelke (1991) as their reaction to the early Landau et al. (1988) work.

Secondly, in the light of contemporary knowledge of early conceptual development, object categories used in both laboratories were perhaps not appropriate to test the assumption that children do not use abstract conceptual knowledge when acquiring new count nouns. Artifacts and foods, although well known to children, are very specific domains. There are two conceptually relevant properties of simple artifacts: actual function, and creator's intention (see e.g. Bloom, 1996). Smith et al. (1996) attempted to demonstrate that shape bias overrides the function identity, but studies by Kemler-Nelson (1995) and her colleagues (Kemler-Nelson et al., 2000) challenge Smith et al.'s results. If the object structure corresponds to the object's function, even two-and half-year-olds extend the name on the function base. Neither artifact nor food domain has a coherent frame theory. Both physical properties and intentions could determine artifact identity. Foods are even harder to conceptualize: cultural, biological, physical or psychological criteria could determine that one of two similar and ontologically close objects belong to the category of foods, while the second one does not.

Thirdly, the assumption that the experimental situation arranged in the Imai et al. and Landau et al. laboratories is like a natural context of naming is questionable. In natural settings it is not usual for two perceptually similar objects not to belong to the same category (co-occurring similar objects typically belong to the same class, except for rare cases of biological mimicra). On the other hand, it is rather unlikely that in a single event the child has to choose between two or more similar objects to determine which one should be named by a given noun. A forced choice task could then disrupt natural naming processes. In Imai et al.'s procedure children were given three choice alternatives, one perceptually similar and two conceptually based: thematic and taxonomic. There is a Polish proverb "Where two fight, the third gains". Here the shape-similar alternative gains twice. If the child has to decide between two conceptual strategies he/she could choose third and simpler perceptual one. And with three choices random level performance is set at the level of 33% (50% for two alternatives), so even if shape-based choices constitute fewer than half of the total, their proportion could be shown above chance.

Last but not least, shape bias can also arise as a consequence of conceptual knowledge. Shape is a causally relevant property of broad range of both natural kind and artifact object categories (e.g. Keil et al., 1997; Bloom, 2001). A naming task requires categorization, contrary to "Which one is like this?" or "Which one goes with this?" questions. Stressful (or unintelligible, or cognitively loaded) laboratory situations could activate a low cost categorization strategy, i.e. following the most essential feature and ignoring less important object properties. If so, shape bias could be a mere recognition mistake (in some sense the child simply recognizes the hat as a birthday cake). If, however, shape bias is a "dumb attentional mechanism", specific to naming (as suggested by Smith et al.) then shape-based decisions should be substantially quicker than category-based (taxonomic) decisions. Automated attentional mechanisms are usually quick, and deliberate conceptual processes (even simplified) are usually slower (Schneider & Shiffrin, 1977). Neither Landau et al. nor Imai et al. controlled the time-course of experimental task performance.

We designed a procedure that allowed us to deal with at least some of these reservations, and employed it in a series of subsequent studies. We followed the Imai et al. (1994) project, but with some notable exceptions. Our materials consisted of objects belonging to four broad ontological categories (animal, plant, inanimate natural kind, artifacts) that were systematically combined to form testing sets. We also included (as a between-group factor) a second dimension of perceptual similarity: texture. We modified the instruction: children were asked to extend words in another foreign child language, but not dinosaur language (children may assume that dinosaur language and cognition is very different from human). In our first study (Haman, 1997, 2000), one half of the subjects were asked to spell the object name in Polish before naming it by a "foreign" word. To reduce the cognitive load, only two alternatives were used in test trials: shape and taxonomic one. In the standard condition the results were similar to those obtained by Imai et al. Subjects (136 preschoolers from 2;11 to 6;7 years of age) made about 58% of shape-biased choices, and the bias was even stronger in the older group (4;6-6;7). In fact, only in this group was the proportion of shape-based choices significantly above random level. However, if children were asked to name the object with a Polish word before a "foreign word", the shape bias disappeared – more than 60% of choices were taxonomically based. There were also notable differences in distribution of shape-biased answers across domains, although interaction with age and condition makes these effects hard to interpret. Yet a very clear result was found in the texture group. Although, in general, proportion of texture-biased choices was lower than the proportion of taxonomic choices, the number of texture biases was highest for inanimate natural kinds (the difference was particularly clear in the Polish name condition). This supports the hypothesis about conceptual bases of perceptual biases in naming, as texture indicates substance which plays a crucial role in determining categorization of inanimate kinds.

In the next step, we computerized the standard procedure to make possible recording reaction times. We used the touch-screen system, so the child's task was simply to touch the chosen alternative on the screen. The reaction time analysis did not support the hypothesis about different cognitive bases of shape-biased vs. taxonomic choices. Shape-biased reactions were a little quicker than taxonomically based, however the difference was too small (between 12 to 71 ms depending on how they were computed) to be explained by a radical difference in cognitive mechanisms. The proportion of shape, texture, and taxonomy-based choices did not diverge from that in the previous, picture-on-paper experiment, but was similar to the mean of the two conditions: standard and Polish name (while only the standard condition was used in the current experiment), and the average number of shape and taxonomic choices was almost equal. Once again we found some texture bias in the inanimate natural kind category.

Why did the computer-based procedure lead to a lower proportion of shape bias? One possibility is that there are two sources of shape bias (and perhaps other perceptual biases). The first one is a simplified procedure of categorization, based on a single property. The second one is the process of detailed comparison of the standard and the test object properties that led to recognizing important similarities between the standard and shape alternatives (both share the same causally important feature), and differences to the taxonomic alternative (that differs on a causally relevant dimension), and then overwriting previous categorization (in contrast to the effect of comparison proposed by Gentner & Namy, 1999). Computerized procedure poses some time-stress that makes detailed comparison harder. Since this is so, the proportion of shape-biased choices should decrease when the instruction explicitly poses time-stress, and should increase when the instruction encourages detailed comparison (with special attention paid to differences). Such a pattern of results was found in the next experiment (Haman, 2001, 2002). Preschoolers asked to make the choices as quickly as possible made less shape-biased decisions (47%) than those who were asked to make a detailed comparison and attend to differences (61%). The proportion of shape-biased choices in a time-stress condition (47%) was not significantly lower than in the standard computerized procedure (49.5%), but item analysis have proved that it was not a random effect.

The studies reported above leave two problems still open. First, the time-stress posed on subjects in the previous experiment was not very strong. Children were asked to make their decisions as quickly as possible; however, the reaction was blocked after a relatively long time (3 seconds). Another problem is that our procedure still exploited a forced choice task with an artificial opposition between similarity and category membership. The experiments reported below were intended to overcome these problems.

Experiment 1

To test how real time-stress influences children's lexical decisions we designed a procedure by which timing posed strong demands on processing speed. We assumed that if our hypothesis about two sources of perceptual bias in naming is correct, a strong interaction between domain and perceptual dimension (shape,

texture) should be expected. These domains in which the main aspects of naive theories involve shape or texture to constrain the criteria of categorization should be biased more than those in which shape or texture is only one of the most salient of the object's features. Inanimate natural kinds are an example of such a domain in which shape is only a characteristic, and texture indicates the defining feature – substance, while in artifacts shape often indicates the defining function, and texture is sometimes the characteristic and sometimes a marginal feature. This was not so clear with the two remaining domains in our study (animals and plants), so we were not expecting any "one-tailed" effect here. There are two possible effects in the comparison group. If shape or texture is involved in local, specific, conceptual knowledge more time for examination may mean the increase of bias. However if children have no detailed theory (except general ontological knowledge), then detailed examination could allow to skip over the perceptual biases that were found in the time-stressed condition. For this reason, it is possible that older children (who have more detailed conceptual knowledge) will be more biased in the comparison condition. As in the previous experiments we assume that reaction times for shape- or texture-biased choices will not be substantially shorter than those for category-based choices.

Method

Participants

126 children (68 girls and 58 boys) from two central Warsaw and two suburban preschools participated.

Design

A 2 x 2 x 2 between-subject design was applied with time-stress vs. comparison condition, perceptual dimension (shape or texture), and age group (3-4 and 5-6 years) as the main factors. The standard object domain (animal, plant, inanimate natural object, and artifact) was the within-subject factor.

Materials

A total of 8 training and 72 test pictures were used in the study. They were the same pictures as in the previous study (Haman, 2000, 2002). Each child was presented with two training trials and twelve test trials. Each trial consisted of three pictures: one of them was a standard, one was the same domain shape or texture-different alternative, and one was cross-domain alternative (similar to the standard). The twelve test trials consisted of all six possible pairs of domains with each domain as standard and as cross-domain alternative once. There were two orders: standard object in the first order was the cross-domain alternative in the second order, and vice versa (e.g. if the mushroom was a standard in the first order, the umbrella was a standard in the second order; see Figure 1.A vs. Figure 1.B). Subjects were randomly assigned to one of the orders. The list of pictures is presented in Table 1, and the an exemplary set of pictures in Figure 1.

Table 1. List of stimuli (two sets for each pair of domains)

Pair of ontological categories	Category 1 standard	Category 1 shape-different (standard's texture)	Category 1 texture-different (standard's shape)	Category2 standard	Category 2 shape-different (standard's texture)	Category 2 texture-different (standard's shape)
Animals / Plants	Humming bird Fish (leaf-like)	Duck Eel		Maple seed Leaf	Pine cone Maple leaf	
Animals / Inanimates	Frog White bear-like animal	Lizard Fox-like animal		Rock (frog-shaped) Cloud (bear-shaped)	Rock (cone-shaped) Cloud (fox-shaped)	
Animals / Artifacts	Dragonfly Rabbit	Caterpillar Dog	The texture-grain size or/and the texture kind (glittering squares, hair, eddies, bubbles etc.) altered	Helicopter Machine (rabbit-shaped)	Airplane Engine-like machine	The texture-grain size or/and the texture kind (glittering squares, hair, eddies, bubbles etc.) altered
Plants / Inanimates	Parsley root Field of flowers	White beet Round field of flours		Icicle River	Snow-pile Lake	
Plants / Artifacts	Red mushroom Apple	Funnel-shaped mushroom Banana		Umbrella Pendant (apple-shaped)	Folded umbrella Diamond-shaped pendant	
Inanimates / Artifact	Mountain (hat-like) Cloud (glove-like)	Irregular rocky mountain Cloud		Hat Glove	Silk-hat Sock	

Procedure

Subjects were tested individually in their schools. The child sat in front of the touch-screen monitor (19" CRT EloTouch monitor was used). The procedure consisted of three phases: introduction, training and test. In the introductory phase the child was familiarized with the touch screen, and a picture of an African child named Simo playing with colorful ball was displayed. Then the subject was told: "Look, this is Simo. He/she [depending on subject's gender] lives in Africa and speaks an African language that is very different from ours – Polish. He/she learns the names of different things in his/her African language. You can help him learn these words. Would you like to do that? – Well. Touch now Simo" At this moment the training phase started. A miniaturized icon of Simo was displayed at the top of the screen, and a picture of the first training standard object was displayed in the center of the screen. The experimenter continued: "Look at this. Simo names it 'kobin' [two-syllable meaningless pseudo word] Could you repeat? – Well, in African this is kobin. Touch the[1] kobin!". Then two gray squares were displayed below the standard picture. The child was told: "You are going to see here [pointing to the gray squares] two other pictures. Help Simo, show him/her which one has to be named kobin" In the time-stress condition children were also told: "But do that quickly, because the pictures will change fast", while in the comparison group they were told "Look at them carefully, don't be in a hurry". Finally, the main question was repeated for all subjects in a simplified form "Where is kobin?". At this moment two choice alternatives replaced the gray squares. In the time-stress condition the standard was removed from the screen 300 ms. after setting on the alternative pictures, while in the comparison condition it remained on the screen. In the time-stress condition the choice alternatives were finally switched off after 2000 ms. In the comparison group decision time was not restricted. Touching one of the pictures or exceeding the maximum choice time (in the time stress condition) automatically started the next training trail (with 1000 ms. between-trail interval). The procedure in the test phase was exactly the same, except that in the time-stress condition the sets for which the child did not choose any alternative were displayed again at the end of the session (each trial could be repeated only once). Both choices and reaction-times were recorded. Typically one session took between 5 and 8 minutes. Twelve test sets were displayed in random order, and objects were also randomly paired with pseudo words. Left or right side assignment of within-category and cross-category alternatives was also randomized, and it was controlled if the child had no strong preference for one side.

Results

Proportions of choices

2 (condition) * 2 (age group) * 2 (shape or texture) * 4 (standard's category) mixed ANOVA with repeated measure in the last factor was run over the proportion of within-category choices. Group means and standard deviations for the proportions of "correct", i.e. category-based, choices are listed in Table 2. There are significant main

[1] Note the article "the" is added here and elsewhere in English translation. The article does not exist in Polish.

Table 2. Mean proportions (and standard deviations) of category-based choices in all groups

Age group	Standard's domain				
	Animal	Plant	Iinanimate	Artifact	N
Shape					
Time-stress cond.					
2;11-4;5	.55 (.348)	.44 (.310)	.29 (.262)	.50 (.355)	16
4;6-7;1	.48 (.373)	.33 (.382)	.42 (.364)	.69 (.373)	21
Comparison cond.					
2;11-4;5	.56 (.285)	.52 (.270)	.43 (.282)	.52 (.326)	21
4;6-7;1	.48 (.321)	.48 (.421)	.35 (.333)	.56 (.379)	16
Texture					
Time-stress cond.					
2;11-4;5	.67 (.272)	.67 (.273)	.45 (.416)	.33 (.430)	7
4;6-7;1	.75 (.304)	.65 (.294)	.51 (.353)	.55 (.259)	18
Comparison cond.					
2;11-4;5	.56 (.316)	.46 (.217)	.64 (.287)	.51 (.292)	13
4;6-7;1	.88 (.166)	.53 (.217)	.44 (.426)	.86 (.215)	14

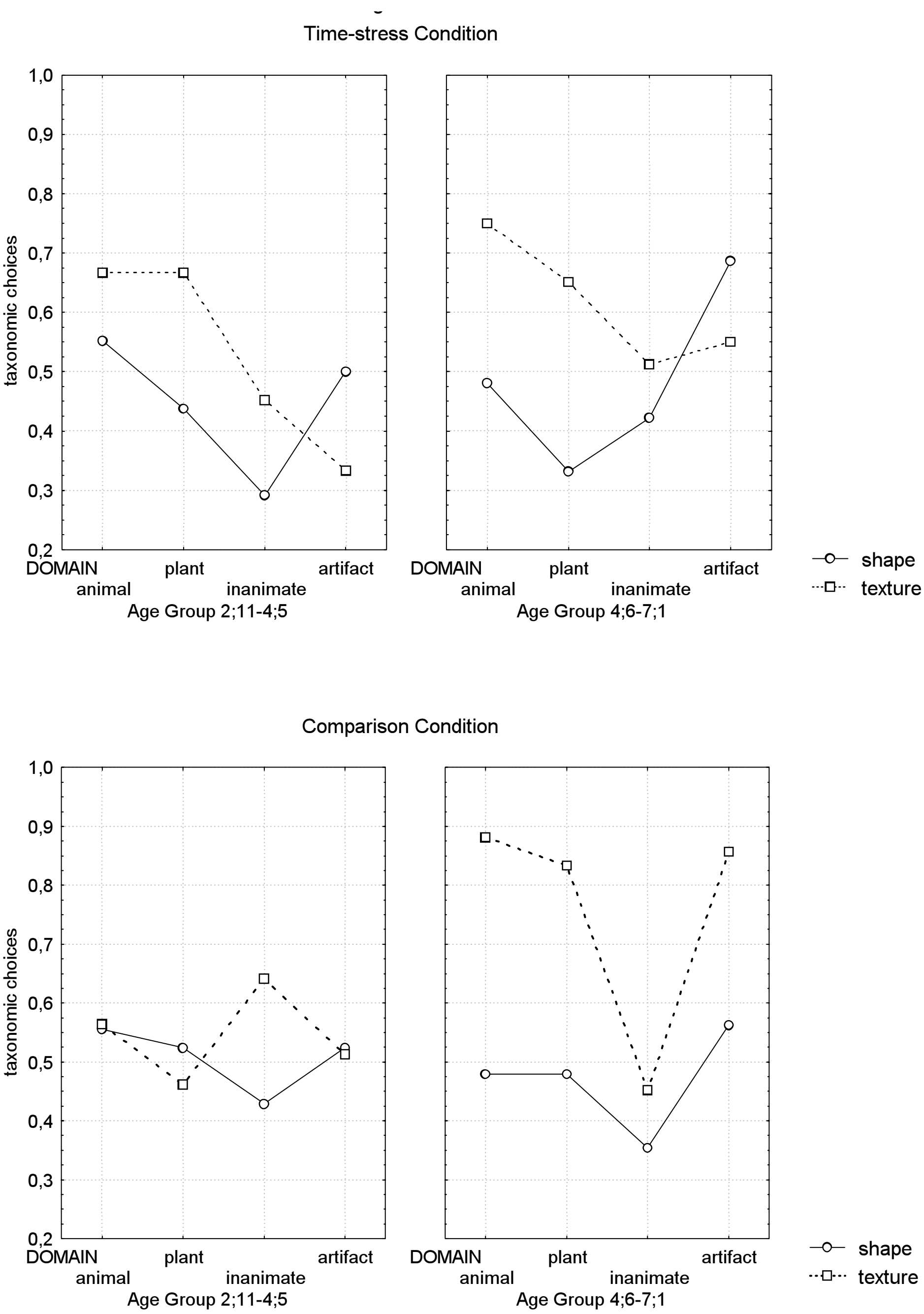
effects of age ($F[1,118]=4.07$, $p<0.046$), perceptual dimension ($F[1,118]=14.05$, $p<0.0003$), and ontological category (domain; $F[3,354]=6.50$, $p<0.0003$), but not condition ($F[1,118]=2.02$, $p>0.16$). There were also several significant interactions of all four factors that will be listed later. Figure 2 illustrates all these effects.

The proportion of category-based and shape-biased choices was almost equal (49% of category-based and 51% of shape-biased), and in any age group and condition does not significantly diverge from 50% (random level). The distribution is not random, however, but highly dependent on domain, with animal and artifact categories less biased, and plants and inanimate natural kinds the most biased categories. Such distribution is similar to that reported in the previous studies, and does not allow for speaking of a strong shape bias.

The results of our previous study with "soft" time stress are not confirmed – the difference is not significant (planned comparison $F[1,118]=0.32$, $p\approx0.57$). It seems that a relatively high number of category-based choices in the comparison group is an effect of the new instruction that did not direct attention to differences between choice alternatives.

Like the previous studies, and as expected from our theory, there was significant interaction between the standard's ontological category and the perceptual dimension ($F[3,354=3.05$, $p<0.03$). In general, there were more texture-biased choices for inanimate natural kinds than for other categories of standard (planned comparison $F[1,118]=5.67$, $p<0.02$). However, the effect is highly dependent on the remaining factors, as captured by interactions with age group and condition, that are at tendency level of significance (domain by age and perceptual dimension $F[3,354]=2.22$, $p\approx0.086$; do-

Figure 2. Distribution of category choices over all design groups



main by perceptual dimension and condition $F[3,354=2;22, p \approx 0.09)$. As noted above, the category of inanimate natural kinds was also highly biased by shape, so it is unclear whether it is an effect of specific conceptual knowledge (as we assume) or simply worse recognition of category members represented in our materials. Previous research with the same materials suggests the first solution. Some weak arguments for it could also be found in the current study. Close analysis of Figure 2 indicates that these doubts are caused by a single cell of the design, i.e., younger children in the comparison condition. In this group inanimates were less biased by texture than other categories. We can speculate that young children use texture for quick decisions about inanimate natural kinds (general knowledge level), but other features for more deliberate categorization. For older children, texture is crucial at both phases of this process (more articulated knowledge at the specific level). Further analysis of choices and reaction times in Experiment 2. will make this speculation more legitimate. However, contrary to our expectations, the distribution of shape bias is similar over all age groups and conditions, except that older children made more shape-biased choices for plants in the time-stress condition, while in younger subjects the most biased category were inanimates.

The remaining effects are not so important for the problems discussed here. In general, children were more biased by shape than by texture. We assume simply that shape is much more universally involved in causal relations than texture. Younger subjects made fewer category-based choices than older, and this concerns especially the texture group (age by perceptual dimension interaction $F[1,118]=4.31, p<0.05$). Age by condition and domain interaction ($F[3,354]=2.92, p<0.04$) has one interesting aspect. In the comparison condition the impact of domain on younger subjects' choices was much weaker that in time-stress condition or in the older group. Another interaction (age by domain) reached tendency level: ($F[3,354]=2.51, p \approx 0.06$). The most prominent component of this interaction is that the artifact category was relatively more biased in the younger than in the older group. We know of no reliable explanation of this effect.

Reaction times

Analysis of reaction times makes sense only in the time-stressed group, as in the comparison group times are extremely dispersed, and probably influenced by several uncontrolled factors. 2 (age) * 2 (condition) * 2 (shape v. texture) * 2 (category vs. perceptually biased choice) ANOVA was run on mean times for each subject (with choice category as repeated measure). Category-based choices were a little slower than shape- or texture biased ($F[1,58]=6.70, p<0.013$), but the difference was only 64 ms., and a much higher difference should be expected if biased and category-based choices were guided by substantially different processes. The results of experiment 2 will provide additional support for this explanation.

Experiment 2

So far we still exploited the forced-choice task. In our final study, forced choice is replaced with subsequent separate decisions concerning each alternative: (1) within-category shape-different, (2) within-category texture-different, and (3) cross-category shape-and-texture-similar. If children really use automated attentional strategies of naming, based on shape (and in some cases on texture), then (at least in the time-stress condition) for most of the trials the proportion of cross-domain shape-similar choices should not be lower than the proportion of within-category shape-similar choices, and should be significantly above the proportion of within-category shape-different choices[2]. At the same time, shape-biased and texture-biased choices should be significantly quicker than category-based ones.

Method

Subjects

Fifty-nine children (31 aged 3;0-4;5, and 28 aged 4,6-7;0) from Warsaw suburban schools participated.

Materials

The same materials as in Experiment 1 were used.

Procedure

The design of the experiment was different from that of the previous one in a single important aspect: each choice alternative was presented to the subject separately, and could be selected or skipped independently of the remaining alternatives in the set. Shape, texture and cross-category choices are here three levels of the within-subject factor (in contrast to separate shape- and texture groups). Taken together, this means that the child examined three choice alternatives: within-category shape-different, within-category texture-different, and cross-category shape-and-texture-similar, and was not restricted to the use a new, "African" word to name only one of them. In other aspects, the procedure was similar to that of Experiment 1. After the introductory story about "Simo-the-African-child" subjects were told that their task is to help Simo to decide if some other pictures shown after the standard should be named with the same "African" word (the child had to touch the pictures to be named with the same word, and to skip those pictures to which the word does not apply). As in the previous experiment there were two between-group conditions: the time-stress condition in which subjects were told to hurry because the pictures change quickly, and the comparison condition in which children were encouraged to examine carefully the standard and the test pictures. The test pictures were displayed on the lower-central part of the screen, below the Simo icon and the standard picture. In the time-stress condition, the standard picture was switched off before the first test alternative onset. Test pictures were displayed not longer than 1500 ms. (or until touched by the child), with 500 ms. delay between them. In the comparison condition the standard was still on the screen during the test alternative display, and each test alternative was shown

---

[2] Note the cross-category alternative is at the same time the most similar to the standard as it includes both shape and texture similarity. Both within-category alternatives differ from the standard on one of these dimensions.

Table 3. Mean proportions and standard deviations of each choice category

Age group	Category of choice Within- -category shape- -different	Within- category texture- -different	Cross- -category similar	N
Time-stress cond.				
3;0-4;5	.35 (.256)	.49 (.272)	.43 (.296)	15
4;6-7;0	.52 (.320)	.68 (.226)	.55 (.254)	16
Comparison cond.				
3;0-4;5	.40 (.270)	.66 (.179)	.44 (.268)	18
4;6-7;0	.67 (.154)	.90 (.107)	.49 (.250)	10
All groups	.46 (.284)	.66 (.250)	.48 (.267)	59

up to 5 seconds. Two training sets and twelve test sets were used (each consisting of one standard and three test alternatives). The order of test sets, and the order of test alternatives in the set were randomized.

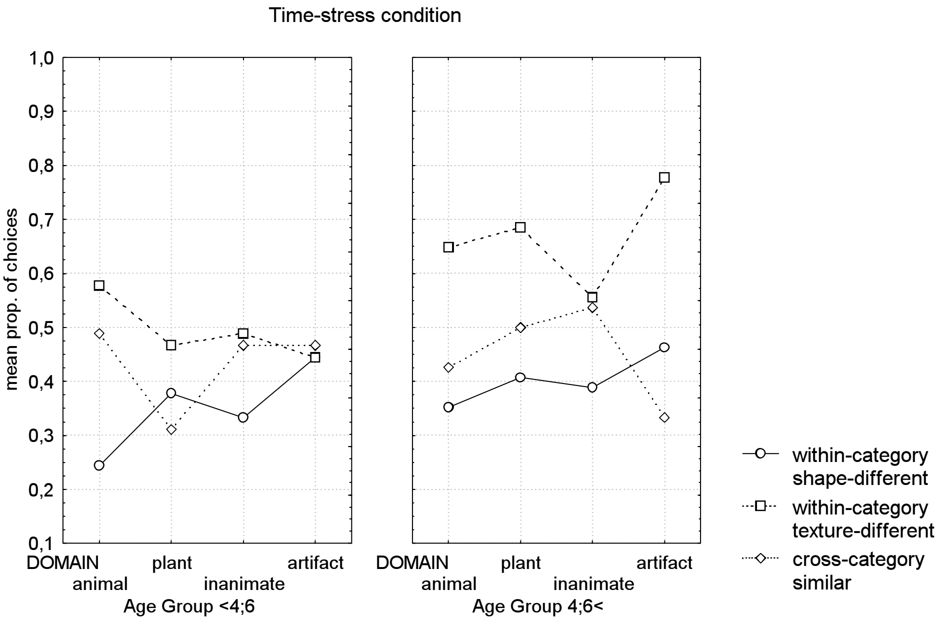
Results

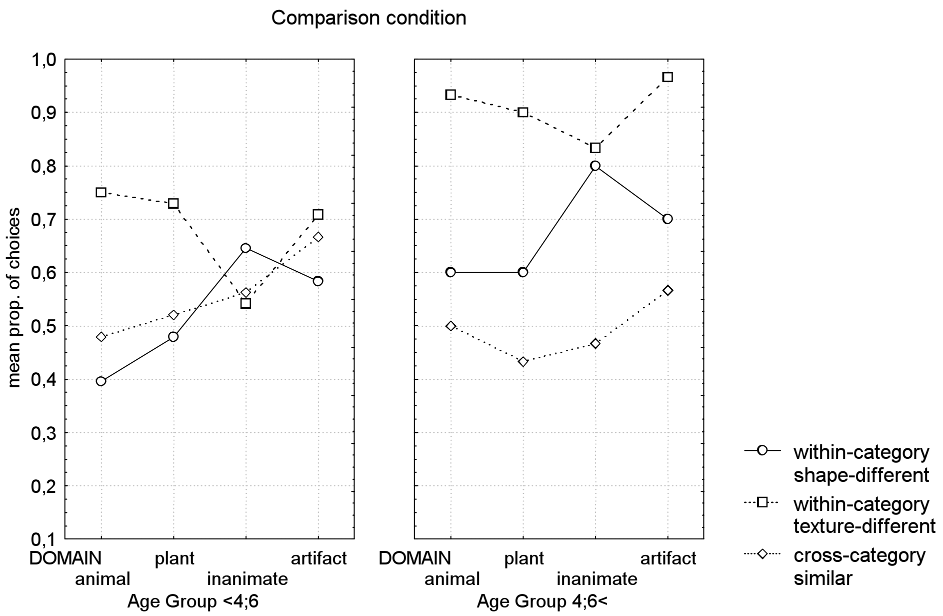
Proportions of choices

2 (age) x 2 (condition) x 3 (choice category) x 4 (standard object category) ANOVA was run on the proportion of choices, with the last two factors as within-subject ones. The strongest effect found in this analysis is that of choice category ($F[2,110]=34.13$, $p<0.0005$). Remember that this time in each of the twelve sets every child separately decided about three objects: two of them belonged to the same ontological category as the standard, but one differed from the standard on the shape dimension, and the second one on the texture dimension. The third object belonged to a distinct ontological category, but was similar to the standard on both perceptual dimensions. The choice was not exclusive, i.e., children could pick up from zero up to all three objects in the set. According to the "dumb attentional mechanism" hypothesis we should expect that only perceptual similarity on the selected dimension (i.e. shape for most of the objects and, perhaps, texture for some objects) would matter, so the cross-category alternative would be preferred, and the texture-different object would be the second choice. Our results falsify this assumption. The same-category, texture-different object was the most frequent choice category, while the same-category, shape-different object and cross-category, shape-and-texture similar objects were chosen with similar frequencies.

There are four interactions that modulate that main effect. First, the general frequency of choices increases in the comparison condition ($F[1,55]= 8.93$, $p<0.005$),

Figure 3. Distribution of proportions of choices between domains, age group, and condition





but the difference is significant only for the two kinds of category-based choices (condition by choice category interaction $F[2,110]=34.13$, $p<0.025$). In the comparison group the within-category shape-different objects were selected more often that the cross-category objects, while the difference in the time-stress group took an opposite direction (both effects significant at tendency level $p<0.1$)

Second, older children made more category-based choices than the younger group (age by choice category interaction $F[2,110]=7.89$, $p<0.001$). Mean proportions and standard deviations for each kind of choice in each group are listed in Table 3.

Third, and most important, the pattern of choices is dependent on the standard category (domain by choice category interaction $F[6,330]=3.58$, $p<0.002$). This time we have obtained a very clear effect of texture on inanimate natural kind naming. However, this does not mean an increase of cross-category choices (planned comparison $F[1,55]=1.09$, n.s.) mechanism hypothesis, but decline of the number of texture-different within-category choices ($F[1,55]=6.87$, $p<0.012$), and at the same time a slight increase of within-category shape-different choices ($F[1,55]=3.35$, $p\approx0.08$), as compared to other domains. Similar effects could be also found for the domain of animals in respect to the shape dimension (proportion of within-category shape-different choices is lower than in other domains – $F[1,55]=8.92$, $p<0.005$, while there is no increase in the proportion of similarity-based choices – $F[1,55]=0.15$, $p\approx0.70$). A three-way interaction among domain, category of choice, and condition reached a tendency level of significance ($F[6,330]=2.11$, $p\approx0.053$; see Figure 3).

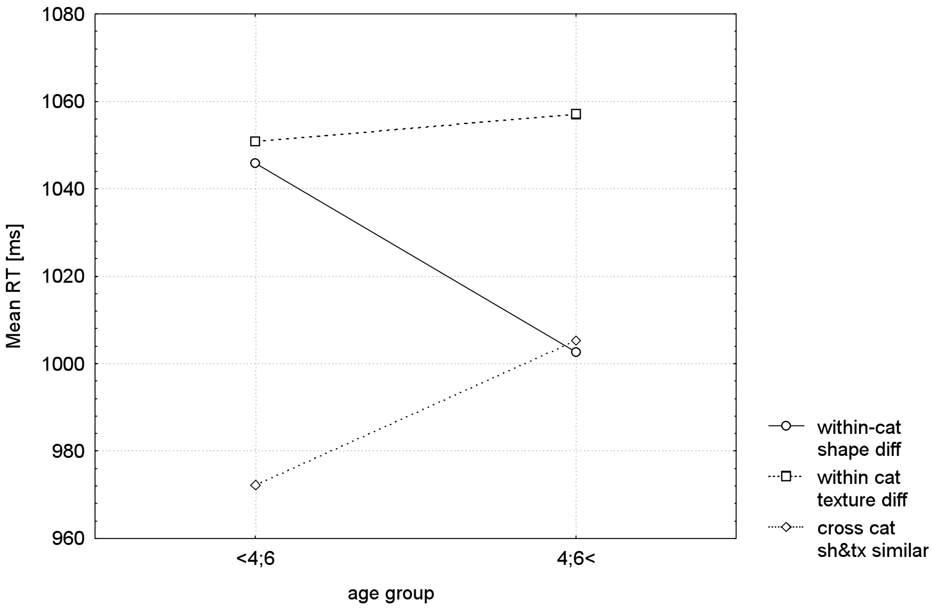
Taking all these effects together, we conclude that children do not follow automatically perceptual cues, but relate them to conceptual knowledge about object kinds. Cross-category choices are not more frequent here than within-category shape-different choices, and also are not more frequent than in the forced-choice procedure. On the other hand they are much less frequent than within-category texture-different choices. In this light, perceptual biases in naming are either simple recognition errors or misuses of conceptually (top-down) rather than perceptually (bottom-up) driven attentional strategies. Reaction time analysis additionally supports this conclusion.

Reaction times

As in the previous experiment, there was no sense to run a full model of ANOVA on reaction times. For the first approximation of the results two ANOVAs (separately for time-stress and comparison groups) were computed in a 2 (age group) * 3 (choice category) design with repeated measures in the last factor. No significant effect or interaction was found in the comparison condition, while in the time-stress group the choice category effect was marginally significant. In general, same-category texture-different choices took a little more time than shape-different, and still few tens of milliseconds more than cross-category choices. Like the previous experiment, the difference is smooth – and never exceeds 80 ms (see Figure 4).

The only way to test detailed hypotheses with standard domain as an additional factor was by paired t-tests (and simple models of ANOVA in some cases), since a more general design should cause a lot of case-drops. Before performing computations we have gathered mean RTs from every design cell in Table 4. The data suggest

Figure 4. General means of three choice categories in both age groups



interesting effects of domain and choice category, as was expected from our model, and some age differences.

The most interesting effects concern choice times of within-category texture different inanimate natural objects in comparison to remaining choice categories and object types, and this is parallel to the results of the analysis of choices. Although in general RTs to texture-different objects were the longest ones, for inanimate kinds in the time-stress group they were quicker than for both remaining categories, although the difference did not reach statistical significance (2 age groups * 3 choice categories ANOVA $F[1,15]=2.87$, $p\approx0.11$). It is however important to note here that the mean RT for within-category different-texture choices is among the lowest means in this experiment. This suggests that analysis of texture is included in a quick categorization procedure for inanimate natural kinds, and the only account for that is conceptually based mechanism. In the time-stress condition, for any other object's domain texture-different choices required more time and, in many cases, the difference reached at least a tendency level of significance. On the contrary, in the comparison condition texture-different choices for inanimates were analyzed longer than in other domains[3], and that indicates that texture is also a prominent dimension of the more deliberate process of categorization of inanimate natural kinds. This effect is much more articulated in older subjects and, together with the differ-

[3] The only exception is the plant category. For preschool children this is located somewhere between animate and inanimate kinds (Keil, 1989).

Table 4. Distribution of reaction times [ms] over choice categories, standard's domains, age and condition

	Choice category											
	Same-category shape-different				Same-category texture-different				Cross-category similar			
	animal	plant	inanimate	artifact	animal	plant	inanimate	artifact	animal	plant	inanimate	artifact
Time-stress												
3;0-4;5	1123	1040	1093	1055	1106	1021	985	1052	981	934	1056	968
4;6-7;0	1087	1035	1058	1021	1092	1068	995	1103	977	1053	999	969
Comparison												
3;0-4;5	2499	2196	2265	2184	2214	2368	2659	2341	2119	2469	2499	2347
4;6-7;0	2199	1937	2078	1957	1939	1918	2327	1940	2456	2269	1976	2454

ences between the younger and older groups in proportion of texture-different choices, it seems to reflect the development of a "naive theory" of inanimate natural kinds (in the comparison condition subjects selected radically fewer texture-different inanimate natural kind objects than any other kind, while younger subjects made somewhat more texture-different choices; see Table 3 above).

In general, the majority of differences were nonsignificant. In the comparison condition shape-different choices took longer for animals than for other object kinds. In this domain shape differences also slowed down decisions in contrast to cross-category choices (time-stress condition) and texture-different choices (comparison condition). These results fit well with the assumption that shape carries essential information about animals. No domain effect was found for cross-category choices.

General discussion and conclusion

In their original paper, Landau, Smith, and Jones (1988) proposed shape bias as the solution to Quine's problem of individuation and categorization of objects. Until starting to learn first words children rely on general perceptual similarity. The first few dozens of words are mostly count nouns that name relatively simple solid objects, and shape is a salient property of such objects, so children pick up a statistical contingency between an object's shape and the word, thus obtaining a powerful instrument of naming and categorization. This mechanism is later modified as new linguistic constructions (e.g., mass-noun syntax for substance) and new perceptual contingencies are learned. However, as Imai et al. (1994) have shown, shape bias persists in some form until early school age.

There is, however, an alternative explanation for children's reliance on object shape in naming. Shape carries important information about causal and functional properties of objects, so it is commonly linked to general ontological categories and to their "theories" that children start to form even before they start to speak. This line of argument is proposed, for example, by Bloom (2002) and Kemler-Nelson and her colleagues (2000; Kemler-Nelson et al. 1995) Taking into account children's limited resources, it is not surprising that they use only a part of the available information. Shape is usually both a reliable and a salient property, so it is a good candidate on which to base categorical and lexical decisions. However, if shape is in sharp contrast to the essential properties of an object, even very young children are able to skip over shape in a word extension task, as Kemler-Nelson (2000) has shown for functional properties of simple artifacts.

In our project, we followed this line of argument, although we were looking for other kinds of evidence. If shape reflects essential (causal and functional) properties of different kinds of objects, then a different pattern of shape bias could be found in distinct ontological categories. In some of them, shape could provide quick recognition cues, in other domains shape marks some subtle distinctions that require detailed examination. For some other kinds of solid objects, shape is perhaps a secondary source of information: rocks, clouds[4], or icicles are identified first through substance, and

[4] Clouds of course are not solid objects, but this is a common illusion that persists sometimes not only in children.

texture is a better indicator here than shape, although shape is also important to determine their identity and category. We have shown such cross-domain differences in our previous experiments. However, if shape is so common a cue to conceptual knowledge, then it is not so easy to differentiate between the predictions of our model and the "dumb attentional mechanism" hypothesis. Both models expect a considerable proportion of shape-biased decisions (although we expect also a relatively high number of taxonomic choices), and the "dumb attentional mechanism" hypothesis allows restricted texture bias as a later learned perceptual contingency, as found by Jones, Smith and Landau (1991) and Jones and Smith (1998) for objects with eyes or shoes. There is, however, one crucial difference. If perceptual biases in naming are bottom-up activated attentional mechanisms, then they should work much faster than conceptually activated (category-based) processes. Our procedure with a computer touch-screen made it possible to test reaction-time differences even with relatively young children.

In the previous studies we have shown that there is no substantial difference in time-course of shape-biased and category-based lexical decisions, and that even in the soft time-stress condition the number of shape-biased choices does not increase (Haman, 2001, 2002). The two experiments reported here provide additional support for the hypothesis of a conceptual mechanism of perceptual biases in naming. Firstly, again no substantial difference in reaction times for category-based and perceptually-biased choices was found, even in the real time-stress condition. Secondly, we found that reaction times correspond in a systematic way to the patterns of lexical decisions. The most prominent is the case of texture-related decisions on inanimate natural kinds. Texture as a cue to an essential object property, i.e. substance, is included into a quick categorization procedure, so reaction times for texture change are shorter in that domain in the time-stress condition, but the number of biased choices is also higher. At the same time, texture is subject to detailed analysis in the comparison condition, so RTs increase, but the proportion of category-based choices decreases again. A similar, though less salient effect, was also found for shape.

Thirdly, the results of experiment 2 indicate that shape bias is in part an artifact of the forced-choice task. Given the possibility to examine each alternative separately, children often reject both shape-similar cross-category object and shape-different within-category object rather than accept the first of them, as should be predicted by the dumb shape-based naming hypothesis. At the same time, children commonly accept the within-category shape-similar alternative (but with exception for inanimate natural kinds because of texture differences). Shape bias (and texture bias for inanimates) is then a negative choice: if the child is not given an acceptable alternative and is forced to choose one he/she will select following the cue that was proved to be conceptually relevant.

Some further reservations could be made to our results. Firstly, we tested children older than those in Landau, Smith and Jones' laboratory. It is still possible that our explanation of perceptual biases in naming applies to a later developmental stage, while Landau et al.'s hypothesis may still be valid as an explanation of the early stages of lexical development.

Secondly, our procedure did not allow fully for differentiation between systematic shape (or texture) bias and mere recognition mistakes. Some differences in the proportion of category-based choices and decision times could then be experimental artifacts. Nevertheless, we hope that the results presented here provide a useful contribution to understanding the perceptual and conceptual bases of lexical development.

References

Bloom, P. (1996). Intention, history, and artifact concepts. *Cognition*, *60*, 1-29.

Bloom, P. (2001). Roots of word learning. In M. Bowerman, S. C. Levinson (Eds.), *Language acquisition and conceptual development*. Cambridge: Cambridge University Press.

Gentner, D., Namy, L.L. (1999). Comparison in the development of categories. *Cognitive Development*, 14, 487-513.

Haman, M. (2000). Domain-specificity, shape bias, and other perceptual biases in word learning. *Polish Psychological Bulletin*, 31, 109-122.

Haman, M. (2001). Poster presented at the *Cognitive Development Society 2nd Biennale Meeting,* Virginia Beach, October, 2001.

Haman, M. (2002). *Pojęcia i ich rozwój* (Concepts and conceptual development). Warszawa: Matrix.

Imai, M., Gentner, D., Uchida, A. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development*, 9, 45-76.

Jones, S.S., Smith, L.B., Landau, B. (1991). Object properties and knowledge in early lexical learning. *Child Development*, 62, 499-615.

Jones, S.S., Smith, L.B. (1998). How children name objects with shoes. *Cognitive Development*, 13, 323-334.

Keil, F.C. (1989). *Kinds, concepts, and cognitive development*. Cambridge, MA: The MIT Press.

Kemler-Nelson, D., Frankenfield, A., Morris, C., Blair, E. (2000). Young children's use of functional information to categorize artifacts: three factors that matter. *Cognition*, 77, 133-168.

Kemler-Nelson, D.G. (1995). Principle-based inferences in young children's categorization: Revisiting the impact of function on the naming of artifacts. *Cognitive Development*, 10, 347-380.

Landau, B., Smith, L.B., Jones, S.S. (1988). The importance of shape in early lexical development. *Cognitive Development*, 3, 299-321.

Schneider, W., Shiffrin, R.M. (1977). Controlled and automatic information processing I: Detection, search and attention. *Psychological Review*, 84, 1-66.

Smith, L.B., Jones, S.S., Landau, B. (1996). Naming in young children: A dumb attentional mechanism? *Cognition*, 60, 143-171.

Smith, L.B. (2001). How domain-general processes may create domain-specific biases. In M. Bowerman, S.C. Levinson (Eds.), *Language acquisition and conceptual development*. Cambridge: Cambridge University Press.

Soja, N., Carey, S., Spelke, E.S. (1991). Ontological constraints on early word meanings. *Cognition*, 38, 179-211.