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Developmental changes within the core of artifact concepts

Adee Matan*, Susan Carey[1]

Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA

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Abstract

Three experiments addressed the relative importance of original function and current function in artifact categorization. Subjects were asked to judge whether an artifact that was made for one purpose (e.g. making tea) and was currently being used for another purpose (e.g. watering flowers) was a teapot or a watering can. Experiment 1 replicated the finding by Hall (1995) (unpublished manuscript) that adults rely on the original function of an artifact over a current function in their kind judgments. Experiments 2 and 3 revealed that whereas the kind judgments of 6-year-olds, like those of adults, patterned with the original function, those of 4-year-olds did not. Four-year-olds were influenced by the order in which the functions were mentioned in the story. Further, in their justifications 6-year-olds and adults referred to the origin of the objects, whereas 4-year-olds virtually never did. We conclude that 6-year-olds have begun to organize their understanding of artifacts around the notion of original function, and that 4-year-olds have not. The data are discussed as they bear on children's understanding of the design stance (Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press).

Keywords: Origin; Intention; Function; Artifact; Categorization; Children; Design stance

1. Introduction

Convergent evidence from many sources suggests that adults adopt an essentialist stance when reasoning about natural kind concepts such as *tiger*, *gold*, *star* (Gelman

* Corresponding author. Unit of Human Development and Education, School of Education, Tel-Aviv University, Tel-Aviv 69978, Israel.

E-mail address: adee@ccsg.tau.ac.il (A. Matan).

[1] Present address: Department of Psychology, New York University, New York, NY, USA.

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and Coley, 1991; Keil, 1986; Medin & Ortony, 1989). In taking this stance toward natural kinds, adults assume that natural kinds have causally deep, hidden properties (i.e. their essence) which determine their surface properties and their behavior in causal interactions with other entities in the world. Since essences determine kind membership for natural kinds, they also are at the core of the meaning of natural kind terms. And indeed, categorization and naming practices provide one source of data in support of psychological essentialism. For example, Keil (1989) showed that adults are sensitive to the origin of surface properties in deciding animal kind: an animal that looks identical to a skunk and acts like a skunk, spraying smelly stuff at enemies, is not a skunk if these features are the result of plastic surgery or a mistaken injection of some mystery chemical during the life of the animal. Moreover, if this animal's parents and babies are not skunks, it is not judged to be a skunk.

Analyzing natural kind concepts in terms of the essentialist stance is closely related to analyzing natural kind concepts in terms of the theories in which they are embedded. A kind's essence includes its causally deepest properties, and intuitive theories specify causal mechanisms, with framework theories (Wellman & Gelman, 1992) characterizing the most general causal processes known to an individual.

Artifacts do not naturally fall in the realm of psychological essentialism nor in the realm of framework theories (Wellman & Gelman, 1992; Wellman & Gopnik, 1994). Thus, while theoretical developments (e.g. the discovery of genes) are highly relevant to understanding the true nature of natural kinds, such developments are irrelevant to the understanding of the true nature of baseball bats (although theoretical developments may allow the successful design of a better bat). Nonetheless, an explanatory structure underlies reasoning about artifacts that is similar to framework theories in the causal structure that framework theories provide. This structure, dubbed by Dennett (1987) as the 'design stance', is an abstract explanatory structure that accounts for an artifact's very existence, its function, its properties and its kind. According to the design stance, an artifact is intentionally created by a designer to fulfill some function. The intended function is the factor which determines the artifact's surface properties, the actual functions it can serve (the intended function as well as others) and its kind. In that sense, the original intended function is the artifact's essence. Thus, a coffee mug is capable of containing liquids because that is what its designer intended. This intended function in turn constrains its form (it must be closed at the bottom, open at the top, graspable when filled with hot liquids, and so on) and also constrains the material from which it can be made (e.g. not ice). Note that the properties which make it function as a coffee mug also allow it to be used as a pencil holder. Nevertheless, the ability to hold pencils is the not the reason the mug came into existence. The cause of its coming into existence is the intention of its designer that it function as a coffee mug.

The deepest causal factor within the design stance as applied to artifacts is the original intended function. If people reason about artifacts in terms of the design stance, they should weight information about original function most heavily in their judgments of an artifact's kind or purpose, just as they weight essential properties over more superficial properties in judgments about natural kind categories. And

indeed, adults do just that. Rips (1989) showed that adults weight the original function of an artifact over its form in kind judgments. For example, adults judged an object that had the features of an umbrella but whose creator had intended it to be a lampshade. Hall (1995) showed that adults weight the intended function over current function in their kind judgments. In one version of his scenarios (the version adapted in the present experiments), Hall told participants about an object that was being used for a certain purpose (e.g. to water flowers). Further, they were told that the object was made by a company for another purpose (e.g. making tea). They were then asked whether the object was a watering can or a teapot. Hall found that original function determined participants' judgments, namely they judged the object to be a teapot. Thus, when making kind decisions, adults weight the intended function of an artifact over both a current function (Hall, 1995) and other properties such as its form (Rips, 1989).

Some researchers have failed to find the expected salience of causally deeper features over more superficial ones. For example, Malt and Johnson (1992) argue that both the intended function and the physical properties of the artifact are important features that influence kind decisions, but that neither absolutely preempts the other. For example, a 'thing manufactured and sold to carry one or more people over a body of water for the purposes of work or recreation' (the function associated with boats) but which is 'spherical and made of rubber, is hitched to a team of dolphins and has a large suction cup that can keep it in one place' (physical features not typically associated with boats) was not judged to be a boat, despite the clearly stated intended function.

Reasoning in terms of the design stance schema, like all causal reasoning, is a form of inference to the best explanation. People infer function from form, and intended function from possible function, as well as drawing inferences in the other direction. According to the design stance schema, intended function is not the most heavily weighted feature because it provides a definition of artifact kind, or because it is the most reliable feature in a prototype structure, but rather because people try to rationalize all they know about an artifact, and the intended function constrains this process. It is likely that in the Malt and Johnson (1992) boat example participants do not accept that somebody would design something to carry people over water in such a manner, given that they know that better boat designs are available.

In sum, there is considerable evidence that adults reason about artifacts in terms of the design stance. The question arises when in development does the design stance become available to organize children's understanding of artifacts and to provide the core of the meaning of artifact terms. Is it available early, perhaps even in late infancy, as is the physical stance and the intentional stance (Baron-Cohen, 1995; Gergely, Nadasdy, Csibra, & Biro, 1995; Leslie, 1994)? Or is it available only later, as is the case for some framework theories such as vitalist biology (Carey, 1985; Inagaki & Hatano, 1996; Slaughter, Jaakkola, & Carey, 1999), which is constructed around age 5 or 6, or an intuitive particulate theory of matter, which is constructed between ages 8 and 12 (Carey, 1991; Piaget & Inhelder, 1974)?

The current literature provides mixed evidence regarding when children reason

about artifacts in terms of the design stance. Young preschool children certainly command some of the components of the stance. First, they know that artifacts are made by people (Gelman & Kremer, 1991). In addition, children as young as 2 years of age (Brown, 1989; McCarrell & Callanan, 1995) and even infants (Kolstad & Baillargeon, 1991) can analyze the functional affordances of objects.

However, there is evidence that even though young children are familiar with elements of the design stance, they do not reason about artifacts in accord with this schema. First, there is some evidence that until age 6 or 7, children do not consistently favor function over form in artifact naming (Gentner, 1978; Keil, 1989; Landau, Smith, & Jones, 1998; but see Kemler Nelson, 1995, with 3–5-year-olds). Further, as the original observations of artificialism by Piaget (1929) showed and as Kelemen (1999a) has recently confirmed, preschool children are prey to 'promiscuous teleological reasoning', meaning that they are indiscriminate in their assignment of purposes. Thus, they claim that both biological and non-biological natural kinds such as tigers, mountains and the sun are 'for' various purposes. Tigers are for roaring, mountains are for climbing and the sun is for keeping us warm. That is, in these contexts they reason about possible functions of objects (functional affordances), but not about the original intended function. Kelemen (1996) also found an age difference in the effectiveness of training preschoolers that the shavings from pencil sharpening are not 'made for anything'. Four-year-olds refused to accept this as possible, even when coached by the experimenter, whereas some 5-year-olds accepted it. In addition, the preschoolers who accepted this as possible were less likely than those who did not to go on to judge that tigers and clouds were 'made for something'. Relatedly, Piaget (1929) reported the gradual untrained disappearance of artificialism over the ages of 6–10.

The present experiments explore artifact categorization in order to address the question of whether the design stance organizes preschool children's concepts of artifact kinds. Hall's (1995) procedure was adapted so that it would be suitable for young children. Participants were told a story about a person who made an object to fulfill one function and another person who used it for a different purpose. The question asked was what the object was. Participants were shown a picture that occluded most of the object, leaving only a part that provided no differentiating information as to the object's kind, and their responses were probed in a forced-choice format.

If preschool children organize their understanding of artifact kinds according to the design stance, their kind judgments, like those of adults, should be consistent with the original intended function. However, if promiscuous teleology and the failure to weight function over form in decisions about artifact kind reflect incomplete understanding of the design stance, we may expect to see developmental changes between ages 4, on the one hand, and 6 or 7 on the other, for it is at these later ages that children robustly weight function over form in artifact categorization and become less promiscuously teleological in their judgments about the purposes of natural kinds, at least in some circumstances (Kelemen, 1996; Piaget, 1929). We therefore began our exploration with 4-year-olds and 6-year-olds.

Given the changes from the Hall (1995) procedure, Experiment 1 established

whether Hall's results with adults would be replicated under these conditions. But first, a pretest established a set of items that 4-year-olds could identify by description.

1.1. Pretest

Experiment 1 required four pairs of items that met the following criteria: 4-year-old children had to be able to identify them from descriptions, and each of the items in the pair could be used to fulfill the function of the other item in the pair (e.g. a teapot could feasibly be used as a watering can and vice versa). Twelve 4-year-olds were provided with descriptions of six pairs of items: plate/Frisbee, watering can/teapot, stroller/shopping cart, belt/tie, bowl/helmet, rolling pin/baseball bat. For each item we described, we asked children to judge which category it belonged to. For example: 'I have a picture of something in my hand. People use it to pour water on the flowers in the garden. Is it a teapot or a watering can?' The items that more than two children failed to identify were not included in the final materials. The final list consisted of the following pairs of items (the number of children failing to identify each object from the description is given in parentheses): teapot (1)/watering can (0), plate (1)/Frisbee (1), bowl (0)/helmet (0), shopping cart (1)/stroller (0).

2. Experiment 1

Before children could be tested, it was necessary to establish that the adult results from Hall (1995) could be replicated using the new methods and procedure.

2.1. Method

2.1.1. Participants

Sixteen adults participated in this experiment. They were undergraduates and staff from the MIT community and American students studying in the Overseas Program at Tel-Aviv University.

2.1.2. Stimuli and procedure

Each participant was presented with four scenarios in which information about the original intended function of an artifact and information about its current function were provided. The items were taken from the list created in the pretest. Participants were then asked to categorize the artifacts.

In each scenario, participants were shown a picture of a wall with an ambiguous unidentifiable object protruding from behind it. For example, the participants saw a spout which could be interpreted as either belonging to a teapot or to a watering can, sticking out from behind a wall (see Fig. 1 for a sample picture). Participants were then shown two pictures of women. They were told that one of the women made the item for some specific purpose (e.g. watering the flowers in her garden – this is the original intended function), whereas the other woman was using it for something

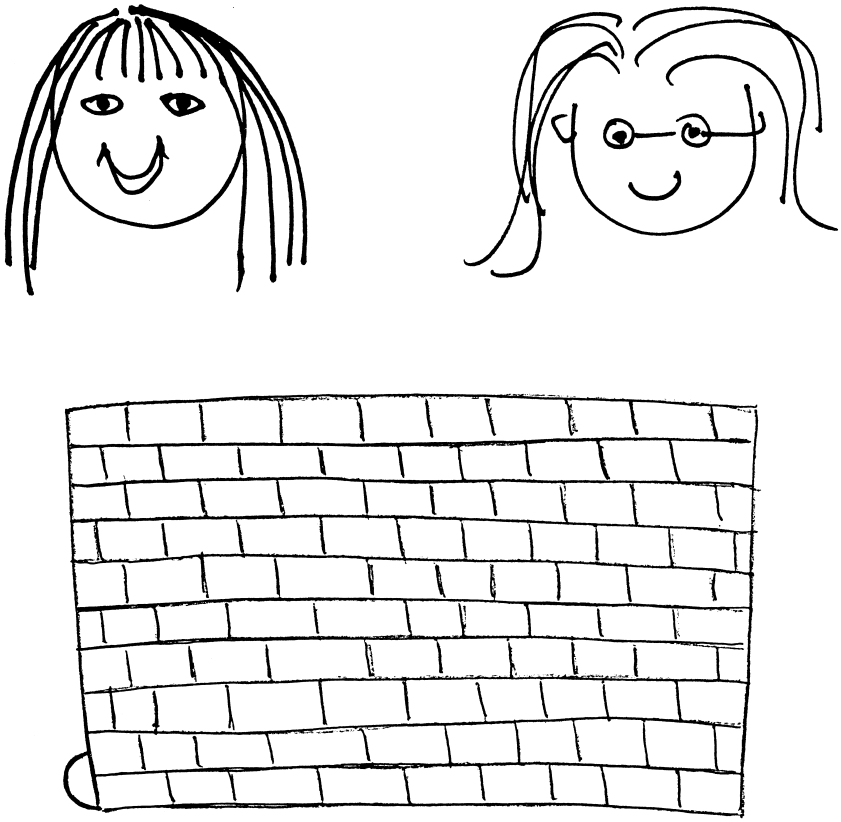

Fig. 1. Example of Experiment 1 drawing of Frisbee/plate item with two women.

else (e.g. for making tea in – this is the current function). Participants were then asked two comprehension questions in order to ensure that they indeed remembered the information they were presented with. Pointing to each of the women in turn, the experimenter asked 'Why did this woman make this?' and 'What is this woman doing with it?'. Finally, participants were asked to categorize the item. After each categorization judgment, subjects were asked to explain their decision by answering the question 'How come?'. A sample scenario follows: 'See this woman, she made this [experimenter points to protruding object] so people could water flowers in their garden with it. And see this woman, she's using it. She's using it to make tea in. So why did this woman make it? And what is this woman doing with it? So can you tell me what this is? Is it a watering can or a teapot?'

To familiarize them with the items and the descriptions of their functions, participants were shown Polaroid pictures of the items prior to the testing session. They were asked to identify the object in the photograph ('What is this?') and to tell the experimenter what can be done with the artifact ('What do you do with an X?'). The experimenter reinforced and corrected the participants' responses using the same

wording for the items that would be used in the test trials. For example, after a participant told the experimenter that teapots are for pouring tea into cups, the experimenter would say 'Oh, so people make tea in them'.

A practice pair of items (baseball bat/rolling pin) was then used to introduce participants to the experimental procedure, with the help of a puppet. The experimenter played out the game with the puppet and profusely praised the puppet when it answered the comprehension questions correctly. When asked to categorize the object, the puppet whispered its judgment into the experimenter's ear so as not to bias the participants' response. The puppet then 'went to sleep' leaving the experimenter and the participant to play the game. After this familiarization procedure, the test portion was carried out, as described above.

For half of the participants, the original function was mentioned first in all four scenarios, and for the other half of the participants, the current function was mentioned first. Also counterbalanced across participants were the original intended design of the item (i.e. whether it was made as a teapot or as a watering can) and the order of mention of the two choices in the test question (e.g. 'Is this a teapot or a watering can?'). Comprehension questions were probed in the same order as they were presented in the scenarios.

2.2. Results and discussion

Participants received a score of 1 if they categorized the object with its original function and 0 otherwise, such that scores could range from 0 to 4. As in Hall (1995), adults' judgments patterned with the original intended function of the artifact. Overall, 80% of adults' categorization judgments were based on the original intended function and their performance was significantly above a chance level of 2 (mean 3.19, SD 0.991) ($t(15) = 5.216$, $P < 0.001$, two-tailed).

An analysis of variance (ANOVA) examined the effects of the following three variables on the number of judgments consistent with original function: the order in which the functions were described (original-fn-1st, current-fn-1st), the order in which the forced choices were given (following-order-of-presentation, not-following-order-of-presentation) and item pair (teapot/watering can, plate/Frisbee, bowl/helmet, stroller/shopping cart). There were no main effects or interactions involving these variables.

The condition in Hall (1995) most comparable to the present experiment was that in which no picture was provided (recall the picture presented in Experiment 1 provided no information) and the description of the original intended function conflicted with that of the current function. In this condition, 83% of Hall's participants' categorization judgments were based on the original intended function, which is comparable to the 80% obtained in Experiment 1.

Although Experiment 1 differed in many details from Hall's paradigm, his basic finding was replicated. Provided no information about an artifact other than what it was made for and another function it can fulfill, adults seem to take the original intended function as determining its kind. However, neither in this study nor in

Hall's studies were adults categorical in their judgments. An analysis of participants' justifications for their choices provides insight into why they were not.

Participants were asked to explain their categorization decision. Each justification was transcribed and coded. In a few instances, participants gave two justifications for a single judgment (e.g. its a plate 'because she made it and you can conceivably throw a plate') in which case both were coded. Two types of justifications dominate the adults' responses: origin and feasibility (see Table 1). Origin justifications (38% of total) are appeals to who made the object and/or what it was made for, such as its a Frisbee because 'that woman made it for that reason', or its a teapot because 'she made it to be a teapot'. But even more common than appeals to the creator and/or the creator's original intent were appeals to the feasibility that a given object could be used for one or another of the functions (53% of total justifications). Examples of feasibility justifications were: its a watering can because 'its a metal watering can – it would be difficult to make tea in something that's plastic', or its a Frisbee 'because you can eat dinner on a Frisbee and its hard to play catch with a plate because it will break'. In addition to these types of justifications adults sometimes appealed to appearance (3%), its a bowl 'because that's what it looks like', or gave unclassified justifications (6%), its a bowl 'because that lady's crazy'.

It seems likely that feasibility justifications play two quite separate roles in adult reasoning in this task. First, often their role may simply be to rationalize the current use, given a kind judgment based on original intended function. That is, the participant used the justification to explain how a plate could be used as a Frisbee, or how a bowl could be used as a helmet. This reasoning was sometimes explicit, as participants appealed both to original function and to the feasibility of the subsequent use (e.g. 'because she made it and you can conceivably throw a plate').

The second role feasibility considerations may play in adult reasoning is as a basis for the judgment of artifact kind. Some subjects may have been reasoning primarily from the two functions an artifact could fulfill to what the artifact must be. If all one knew about a given object was that it could be used for two functions – to eat dinner

Table 1
Percent of each justification type[a]

Justification type	Age			
	4-year-olds		6-year-olds	Adults
	Experiment 2	Experiment 3		
Origin	16	7	27	38
Feasibility	–	4	21	53
Use	40	36	17	–
Appearance	27	35	29	3
Unclear	18	17	6	6

[a] There were cases where participants gave more than one justification and cases where no justification data were collected. Dashes indicate that the justification type was never given by the participants. The percentage was calculated out of the total number of justifications given.

off and also to be thrown from person to person in an outdoor game – one might reason that it is more likely to be a Frisbee than a plate because the properties of Frisbees lend themselves to be used as a plate more feasibly than vice versa. If this form of reasoning sometimes underlay participants' judgments, we can hypothesize that adult judgments were not 100% consistent with original intended functions because our materials did not succeed in making it equally feasible that each object could be used for the other function. Because adults considered this issue, they sometimes overrode the information about original intended function. Most adults consistently judged that the artifact was the kind it had been made to be (three or four of the four judgments), but three adults made only one or two of the four artifact kind judgments consistent with original intended function. Table 2 shows that these three participants never justified their kind judgments, even those consistent with the original functions, by appeals to who made the objects. Rather, their judgments were overwhelmingly justified by appeals to feasibility, as would be expected on this hypothesis.

2.3. Conclusions

The procedure of Experiment 1 revealed the same sensitivity to artifact origin in determining artifact kind as Hall's (1995) procedure did, and therefore can be used to probe for this sensitivity on the part of children. Adults' lack of categorical reliance on the original intended function – both in Hall's original experiment and in Experiment 1 – along with an analysis of the justifications in the present study help clarify the nature of the process by which adults determine artifact kind. Adults do not simply take the original intent of the artifact's maker as determining kind, for that information is clearly stated in these studies. If the original intended function provided necessary and sufficient conditions for determining artifact kind, we would have expected 100% of adults' judgments to be consistent with this factor. We would also have expected more of adults' justifications to be a simple reference to origins: 'its a bowl because he made it to hold soup in'. The high proportion of feasibility justifications shows that the adults were reasoning about an object's features, as well as about its origin. However, the information about features derived from current function and the information about features derived from original

Table 2
Percent of adult justification types[a]

Justification type	0, 1 or 2 judgments consistent with original function ($n = 3$)	3 or 4 judgments consistent with original function ($n = 13$)
Origin	–	46
Feasibility	83	46
Use	–	–
Appearance	8	1
Unclear	8	5

[a] Dashes indicate that the justification type was never given by the participants.

function are not always consistent with each other. For example, something made of ceramics to be a plate could not very easily be used as a Frisbee. Therefore, the information that it was used as a Frisbee can be taken as counter evidence to the claim that it was made to be a plate.

Nevertheless, to the extent that we succeeded in making it plausible that each of these items be used for both functions, these data show that the adults take original intended function to be more important than current function in determining artifact kind, as expected from the fact that original intended function is the deepest causal factor within the design stance. We now turn to the children.

3. Experiment 2

3.1. Method

3.1.1. Participants

Twenty-four 4-year-olds (mean age 4 years 7 months, range 4 years 1 month to 4 years 11 months), 11 girls and 13 boys, and 16 6-year-olds (mean age 6 years 6 months, range 6 years 0 months to 7 years 0 months), 10 girls and 6 boys, participated in this experiment. Six additional 4-year-olds were tested but were not included: one child refused to complete the experiment, and another five could not respond correctly to the comprehension questions on two or more items. Participants were recruited from Greater-Boston day-care centers and schools. They were all native speakers of English and from multi-ethnic middle- to upper-middle-class populations.

3.1.2. Stimuli and procedure

The stimuli and procedure were the same as in Experiment 1, except for adjustments needed because children sometimes failed to respond correctly to the comprehension questions. When participants gave incorrect responses to the comprehension questions, the scenario was repeated, and comprehension was probed again; successful responses to these questions were required before the test question was asked. If children needed the information repeated more than three times or seemed to be losing their patience, the experimenter simply proceeded to ask the test question (this occurred four times in 96 scenarios). In addition, subjects who could not eventually respond correctly to the comprehension questions on more than one item were excluded from the analysis and replaced ($n = 5$).

3.2. Results

As in Experiment 1, participants received a score of 1 if they categorized the artifact according to its original function and 0 otherwise, such that scores could range from 0 to 4. An ANOVA examined the effects of the following variables on the number of judgments consistent with original function: age (4, 6), the order in which functions were described in the scenario (original-fn-1st, current-fn-1st), the order in which the forced choices were given (following-order-of-presentation, not-

following-order-of-presentation) and item pair (teapot/watering can, plate/Frisbee, bowl/helmet, stroller/shopping cart). There were main effects of age ($F(1,31) = 6.421$, $P < 0.05$) and order of function description ($F(1,32) = 6.484$, $P < 0.05$). Six-year-olds categorized more artifacts according to their original function (86%) than 4-year-olds did (66%), and more artifacts were categorized according to their original function when the original function was mentioned first in the scenario (84%) than when it was mentioned second (64%). There was an interaction between item and order ($F(3,96) = 2.801$, $P < 0.05$) and a marginally significant interaction between age and order ($F(1,32) = 2.078$, $P = 0.089$). That is, the order in which the original function was mentioned in the scenario influenced subjects' categorization judgments for some items more than for others, and the order of mention of the original function had a different influence on the response pattern of the two age groups. No other interactions were significant. It was unclear what the effect involving item was due to, but as one 4-year-old pointed out, shopping carts have a double function – namely, part of the design of most American shopping carts is a seat specifically made for carrying around small children. Therefore, the item pair shopping cart/stroller was replaced in Experiment 3. The marginal interaction between age and order of mention was due to the fact that the order of mention affected the 4-year-olds' judgment patterns but not the 6-year-olds' (see following).

Given the marginal interaction between age and order, we analyzed the data within each age group separately. Overall, 66% of 4-year-olds' categorization judgments were consistent with the original function (mean 2.625, SD 1.173), which was different from chance ($t(23) = 2.611$, $P < 0.05$, two-tailed). An ANOVA examined the effects of the following variables on the number of judgments consistent with original function: the order in which functions were described in the scenario (original-fn-1st, current-fn-1st), the order in which the forced choices were given (following-order-of-presentation, not-following-order-of-presentation) and item pair (teapot/watering can, plate/Frisbee, bowl/helmet, stroller/shopping cart). There was a main effect of order ($F(1,20) = 8.588$, $P < 0.01$), that is, 4-year-olds categorized more items according to their original function when the original function was mentioned first in the scenario (81%) than when the original function was mentioned second in the scenario (50%). There were no other main effects or interactions involving these variables.

Turning to the 6-year-olds, the comparable ANOVA yielded no main effects or interactions involving these variables. As mentioned earlier, 86% of the 6-year-olds' categorization judgments were consistent with the original function (mean 3.4, SD 0.814), which is significantly above chance ($t(15) = 7.064$, $P < 0.001$, two-tailed).

Consideration of the 4-year-olds' and 6-year-olds' justifications confirms that the processes that underlie 4-year-olds' judgments differ from those of 6-year-olds and adults. Like adults in Experiment 1 (Table 1) children's justifications appealed to origin ('because that's how she made it', or 'because she made it as a watering can'), feasibility ('because you can throw plates back and forth if its plastic'), and appearance ('because its round'). In addition, children frequently made a type of justification not seen among adults, namely simple appeals to use (its a Frisbee, because 'its to throw', or its a bowl because 'there's soup in them'). Use justifications differ from

feasibility justifications because they are simple references to one of the functions in the story without mention of any of the properties of the object that would make it feasible (or not) that the object be used in that way. Finally, children fairly frequently provided unclassifiable justifications ('because some are small and some are big', 'because it is'). In a few cases no justifications were given.

The first lesson to draw from Table 1 is that the 4-year-olds' justifications are very different from those of the adults, and that the 6-year-olds' fall in between. Adult justifications appealed to origin or feasibility (91% of all justifications), and to a lesser extent so did the 6-year-olds' (48%), whereas only 16% of the 4-year-olds' justifications were of these two types. No adult justifications and only 17% of the 6-year-olds' justifications were appeals to simple use, whereas almost half of those of the 4-year-olds were of this type. The four-year-olds were much less likely to appeal to origin (16% of all justifications) than were the 6-year-olds (26%) or adults (38%). In addition, when 4-year-olds did appeal to origins their justifications, for the most part (62%), simply mentioned who made the object ('because she made it'). In contrast, adults' appeals to origins rarely were of this type (15%); rather, adults mentioned the purpose for which the object had been made ('because she made it for eating dinner off') or the kind of artifact it was made to be ('because she made it to be a plate'). Six-year-olds' appeals to origins were of both these types (simple 46%, elaborated 54%).

The analysis of justifications underscores that 4-year-olds are barely sensitive to original intended function as a basis for artifact kind judgments, at least under the conditions of this task. However, there were some indications that the children found it difficult to *remember* the information about original intended function and current function in these scenarios. Upon first being given the comprehension questions (Why did this woman make it? What is this woman doing with it?), 35% of the 4-year-olds' and 30% of the 6-year-olds' responses were incorrect; they either mixed up the two functions or responded they didn't know. As mentioned earlier, participants had to correctly respond to the comprehension questions before the test question was asked. Participants who even after having the information repeated could not respond correctly to both comprehension questions on more than one item were excluded from the analysis. No 6-year-olds were excluded according to this criterion, whereas five 4-year-olds were.

If the 4-year-olds are having difficulties remembering the information about original intended function, it would hardly be surprising that they would not base their judgments on it. Of course, the memory hypothesis is not independent of a conceptual change hypothesis. Memory failure in this situation may reflect the fact that the distinction between original intended function and current function is not particularly salient or meaningful to 4-year-olds. If that is so, we would expect children who spontaneously remembered the information to be more likely to categorize the object on the basis of original function. And indeed, this seems to be the case. Of the 24 4-year-olds, six passed the comprehension questions on all four pairs of items the first time they were presented, and eight did so for three of the four pairs of items. These two groups of children categorized on the basis of original function 71% of the time. The remaining ten children required multiple retellings of the

scenario before they passed the comprehension questions for two or more pairs of items. These children categorized on the basis of original function only 57% of the time. Although the differences between these two groups was not significant ($t(22) = 0.260, P > 0.05$), these results are suggestive of the fact that better memory is associated with better performance.

3.3. Conclusion

Four-year-olds performed only slightly better than chance in Experiment 2. This level of performance overestimates the sensitivity of 4-year-olds to the original intended function in determining artifact kind, given that five children (of 29, 17%) were excluded from the sample because they could not remember the information in the scenarios. The scenarios are very simple. The only information the child had to remember is who made the object and for what purpose, on the one hand, and who was using the object and for what purpose, on the other. If the design stance organizes 4-year-olds' understanding of artifact kinds, this information should have been salient.

However, the 4-year-olds had difficulties in remembering this information. Moreover, the order in which the functions were mentioned influenced their judgments and their justifications almost never referred to who made the object. All of these suggest that 4-year-olds, as a group, do not yet organize their understanding of artifacts under the explanatory schema provided by the design stance.

What of 6-year-olds? In some ways, their data are identical with the adult data: their kind judgments are overwhelmingly consistent with original intended function and they are uninfluenced by the order of mention of the functions. Moreover, some of their justifications reflect the integration of all the sources of information (original intended function, properties inferred from current and intended uses) that adults use. However, unlike adults, the 6-year-olds do not predominantly rely on the origins or the feasibility of the artifact in their justifications and are as likely to rely on use or appearance in their justifications. This may reflect a partial understanding of the design stance schema. One can make judgments which are consistent with the original intended function by reasoning that the person who made the object gets to decide what it is, or gets to decide what it is called. Both of these fall short of the full adult explanatory schema, which provides an account in terms of the design stance for why it is that the person who makes it gets to say what it is and what it is called. The reason is not an arbitrary one. The creator has this prerogative because he or she had the intention of creating the artifact for a specific purpose. Six-year-olds, as a group, may still be in the midst of constructing the full explanatory schema which covers the intended function, origin, properties and possible uses of artifacts.

The memory difficulties of the 4-year-olds in Experiment 2 are worrying. Perhaps their understanding of the design stance is underestimated: the children may have had memory difficulties because the information about intended function was not salient enough. Alternatively, the processing resources needed to remember the information may have interfered with the inferential process needed to determine artifact kind.

In Experiment 3, the procedure of Experiment 2 was modified to make the information about original function and current function more salient. A more elaborate story stressed the designer's intentions and the process of making the artifact. In addition, several modifications were introduced to ensure that children remembered the relevant information. First, the protagonists were differentiated by sex. Second, pictures of the protagonists, accompanied by pictures associated with the relevant functions of the artifacts, were left in view of the participants throughout the experiment. If 4-year-olds consider original intended function to be central to artifact categorization, their performance should be much better in Experiment 3 than it was in Experiment 2.

If, on the other hand, the design stance does not organize 4-year-olds' representations of artifact kinds, we may expect their performance in Experiment 3 to be worse than that in Experiment 2. The procedure of Experiment 3 provides external aids to remembering which function is associated with which person; the child does not have to rely on remembering which person made the object and for what purpose in order to differentiate the people. Therefore, we expect all children to pass the comprehension questions in Experiment 3, unlike in Experiment 2, in which 20% of the 4-year-olds tested had to be replaced for failing to finish the procedure or for failing the comprehension questions. Thus, in Experiment 3, we will not be selecting 4-year-olds based on whether they find who made the object to be a salient piece of information.

Given the 6-year-olds' adult-like performance in Experiment 2, only 4-year-olds were included in Experiment 3.

4. Experiment 3

4.1. Method

4.1.1. Participants

Participants were 24 4-year-olds (mean age 4 years 6 months, range 4 years 0 months to 4 years 11 months), 10 girls and 14 boys. They were recruited from Greater-Boston day-care centers and nursery schools. They were all native speakers of English and from multi-ethnic middle- and upper-middle-class populations. Three additional children participated in this experiment but were excluded from the analysis. Two were excluded because they could not answer three or more of the comprehension questions correctly, and the third was excluded due to an experimenter error.

4.1.2. Stimuli and procedure

Each child was presented with four scenarios in which contrasting information about the original function and the current use of the items was described. The children were then asked to categorize the items.

As in Experiment 2, the items in each pair were chosen such that each item could plausibly be used in the capacity of the other item in the pair. Three of the pairs of

items were the same as in the previous experiment, while the stroller/shopping cart pair was replaced with the baseball/rolling pin pair. In each scenario the children were shown an ambiguous unidentifiable object occluded by a wall and two pictures of people, a man and a woman. They were told that one of the two people had made the object for a certain purpose whereas the other one was using it in a different capacity. In the scenarios of Experiment 3, general traits of the artifacts which were common to both items in the pair were described (for example, long and smooth for baseball bats and rolling pins) as were the desires of the protagonists (for example, this woman wanted something to hit baseballs with, and this man needed something to roll out cookie dough with). In addition, the process of creating the artifact was described at length to highlight the importance of the original function of the artifact, thus giving the children a better chance of succeeding on the task. The stories were also accompanied by colorful drawings that were associated with the original function of the artifact being described and with its current use. For example, the story about something that was made to hit baseballs with and was being used to roll out cookie dough was accompanied by a picture of a man and a woman. A picture of a baseball cap and a baseball was displayed next to the character that created the artifact, and a picture of some cookie dough and a cookie cutter was displayed next to the character who used it. All the drawings were left in full view of the children throughout the session. After the respective stories were told, the experimenter briefly repeated why a given character made the item and what the other character was using it for. The child was then asked to categorize the item. After the child gave her response, the experimenter asked two comprehension questions to see whether she indeed remembered the information that was presented. Following is a sample scenario with the test and comprehension questions (the entire set of scenarios is given in Appendix A):

See this woman? She made this thing [experimenter points to protruding object]. Now this woman wanted something to hit baseballs with in the park. But she didn't have anything to do that with. So you know what? She decided to make something. So she went to the store and bought all the materials she needed so she could make something to hit baseballs with. She then went home and she spent the whole day carefully making something that was long and smooth. She said to herself: 'This is going to perfect for hitting baseballs with'. She then went to the park. But you know what? She forgot this thing on a bench next to her house.

But you know what, see this man? He's her neighbor. Now this man found this thing [experimenter points to protruding object] on the bench. He had been looking for something to roll out cookie dough with for a long time. He walked up to the bench and said: 'Hey, look what I found on this bench. It's exactly what I needed for rolling out cookie dough. It's long and smooth and it's just the right size'. So he picked it up and took it to his kitchen and he rolled out cookie dough with it.

So remember – this woman made this to hit baseballs with, and this man used it to roll out cookie dough. So can you tell me what this is: is it a baseball bat or a rolling pin? Now can you tell me why this woman made this? And what was this man doing with it?

The same familiarization procedure used in Experiment 2 was used in Experiment

3. The counterbalancing measures were also the same, with the additional measure of whether the man or the woman made the item.

4.2. Results

We succeeded in eliminating the children's difficulty in remembering which protagonist was associated with which function, as seen by the small number of errors on the comprehension questions. There were a total of eight comprehension questions for each participant, two for each item. Out of a total of 192 comprehension questions, only six were not the exact answer we were looking for, and were mostly of the nature 'Why did he make it? Because he needed to'.

As in the previous experiments children received a score of 1 if they categorized the artifact according to its original intended function and 0 otherwise. Therefore, given that there were four scenarios, scores ranged from 0 to 4. Sixty-one percent of the 4-year-olds' categorization judgments were based on the original function; the average number of judgments each child made consistent with original function was no different from the chance level of 2 (mean 2.45, SD 1.38) ($t(23) = 1.6$, $P > 0.05$, two-tailed).

An ANOVA examined the effects of the following three variables on the number of judgments consistent with original function: the order in which the functions were described (original-fn-1st, current-fn-1st), the order in which the forced choices were given (following-order-of-presentation, not-following-order-of-presentation) and item pair (teapot/watering can, plate/Frisbee, bowl/helmet, rolling pin/baseball bat). There was a main effect of order ($F(1, 22) = 5.037$, $P < 0.05$), indicating that the likelihood that children classified the object according to original function varied according to whether the original intended function of the artifact was mentioned first in the scenario (79%) or whether the current function was mentioned first in the scenario (44%). There were no other main effects or interactions involving these variables.

In order to compare the 4-year-olds' performance in Experiments 2 and 3, an ANOVA examined the effects of the following three variables on the number of judgments consistent with original function: experiment (2, 3), the order in which the functions were described (original-fn-1st, current-fn-1st) and the order in which the forced choices were given (following-order-of-presentation, not-following-order-of-presentation). There was a main effect of order ($F(1, 40) = 16.29$, $P < 0.001$). That is, overall, 4-year-olds categorized more artifacts according to their original function when the original function was mentioned first in the scenario (80%) than when it was mentioned second in the scenario (47%). There were no other main effects, or any interactions between the factors – specifically there were no main effects of experiment or any interactions involving experiment. Thus, children's performance did not differ between the two experiments.

The justifications participants gave in this experiment were very similar to those of the 4-year-olds in Experiment 2 (see Table 1). Most of their justifications referred to appearance (35%) or use (36%). In spite of the elimination of the memory

problems, there certainly was no increase of justifications referring to origins in Experiment 3 (7%) compared to Experiment 2 (16%).

4.3. Conclusion

The scenarios of Experiment 3 highlighted the designer's intentions and the process of making the artifact. The changes introduced in this experiment eliminated the memory problems that plagued the 4-year-olds in Experiment 2. Nonetheless, 4-year-olds in Experiment 3 still failed to categorize the artifacts according to their original functions. The data from 4-year-olds in the two studies were identical in nearly every aspect: their susceptibility to the order of mention of the functions in the scenarios and their patterns of justifications. If anything, 4-year-old performance was worse in Experiment 3; the proportion of kind categorizations consistent with original intended function fell from 66 to 61%. Presumably, performance was slightly (though not significantly) better in Experiment 2 because the participants in that study were selected to a greater degree. A higher percentage of participants in Experiment 2 (20%) had to be replaced due to failure to answer the comprehension questions than in Experiment 3 (8%).

In the context of these studies, who made the object was not a salient piece of information for preschool children. When who made the object was the only basis for distinguishing between the two protagonists (Experiment 2), 4-year-olds had great difficulties remembering the information in the scenarios and passing the comprehension questions. In Experiment 3, children passed the comprehension questions but they could do so by simply looking at the indicated protagonist and their associated symbols (baseball cap, cookies). Who made the item apparently played little role in either situation. It is striking that the 4-year-olds in Experiment 3 did not use original function as a basis for their decisions about artifact kind. That one of the protagonists had made the object was stressed in the scenario and repeated immediately before the forced choice question, and yet this fact played no significant role in artifact classification.

5. General discussion

The data from Experiment 1 are consistent with the hypothesis that adults' decisions about artifact kind result from inference-to-best-explanation reasoning within the framework provided by the design stance. First of all, adults weighted original intended function more than current function in deciding artifact kind. Second, both in Experiment 1 and in Hall's data, only about 80% of adults' judgments were consistent with original intended function, indicating that this factor does not provide necessary and sufficient conditions for decisions about artifact kind. The feasibility justifications directly reflect adults' inference-to-best-explanation reasoning. It is likely that, sometimes, adults inferred features the object must have in order for the current function to be possible and if these were inconsistent with the stated intended function, they overrode the information about the intended function in their decisions about kind.

As a group, 4-year-olds, unlike adults, do not take the maker's intent regarding the function of an artifact he or she created as central to what the artifact is. Unlike adults, they do not find the original intended function of the artifact to be more relevant to artifact kind than the artifact's current function, and they do not appeal to the maker's intent in their justifications of their categorization decisions. They were strongly influenced by the order of mention of function, unlike 6-year-olds and adults. If preschool children considered artifact kind to be determined by original intended function, the order of mention should not have affected their judgments, as was the case for 6-year-olds and adults. Instead the first function mentioned played a large role in determining what kind of thing the object was. The present experiments suggest, therefore, that the design stance does not organize preschool children's understanding of artifact kinds.

There are two broad possibilities as to why 4-year-olds fail to demonstrate an understanding of the design stance in Experiments 2 and 3. First, 4-year-olds may not yet have constructed the design stance. Second, they may indeed understand the design stance, but fail to see its relevance in the present studies, perhaps because they have not yet structured their understanding of artifacts in terms of it.

We favor the first possibility. It is difficult to see what the design stance might be for other than explaining the existence, functions, properties and kinds of designed objects, namely artifacts. Also, data from several sources suggest that preschool children do not yet have the capacity to reason from this stance. First, many studies show that preschool children do not yet consistently weight function over form in their decisions about artifact kind (Gentner, 1978; Keil, 1989; Landau et al., 1998; but see Kemler Nelson, 1995[2]). If children do not explain an artifact's existence, properties and kind in terms of the function the designer intended it to have, it is not surprising that they do not take function as particularly more important than form when making kind decisions.

Second, when asked directly what an object was 'made for', preschool children do not consistently prefer the intended function over a current function. Matan (1997) asked 4-year-olds to create an artifact on their own (e.g. for helping pour lentils into a bottle), and then use it for a serendipitous function (e.g. for covering up the blue parts of a blue and yellow object). The children were then asked what they made the artifact for. Four-year-olds found the serendipitous and the original function equally good responses to that question.

Similarly, German and Johnson (1997) contrasted an originally intended function (e.g. something made for collecting raindrops) with a current intended function (currently used for trapping bugs) and asked 5-year-olds what they thought the

[2] In contrast with most of the studies, Kemler Nelson (1995) showed that there are conditions under which 3–5-year-olds will use function as opposed to form in determining category membership. She explains that the reason that she found that children can rely on function in their kind judgments is that in her experiment the causal relations between function and form were made extremely clear. However, Kelmer-Nelson does not deny form a role in children's judgments and claims that neither form nor function can be said to be dominant in children's kind judgments.

artifact was for. They also found that children did not find the original function to be more important than the current function in determining what the artifact was for.

Third, additional support for the hypothesis that preschoolers do not understand the design stance is that they say that all objects are 'for' something, even natural kinds (Kelemen, 1996; Piaget, 1929). Preschoolers' failure to distinguish artifacts from whole natural kinds with respect to the questions such as 'what are telephones for' and 'what are tigers for' is suggestive that they do not fully understand 'for' in this context to mean 'made for'. If this were a trivial pragmatic or semantic failure, it should be easy to train children on its meaning. This is exactly what Kelemen (1996) attempted to do: she tried to train 4- and 5-year-olds that some things are not made for anything. She sharpened a pencil in front of the children and explained that whereas the tip is made for writing, the pile of sharpenings is not made for anything. She then asked participants whether they thought the shavings or the tip were made for something or not made for anything. Children participated in two training sessions. Almost half of the children (11 out of 24) insisted in both sessions that the 'pile of stuff' was made for something, whereas only seven demonstrated the adult response of affirming that the pencil tip was made for something whereas the 'pile of stuff' was not. Kelemen also found that it was very difficult, if not impossible, to persuade them to the contrary. All children had to do in order to 'succeed' on the training was to repeat what the experimenter told them. Therefore, children's resistance to training suggests that they have a different understanding of what 'made for' means. If they do not understand what 'made for' means, it is not surprising that they say that tigers are for being seen at the zoo.

Elsewhere, however, Kelemen (1999a) argues that preschoolers are able to distinguish between functions of artifacts (and body parts) and say which of them the artifact is 'for'. She argues that preschoolers understand that the function that the artifact is 'for' is the function that the artifact was originally created to 'do'. Such an understanding would be indicative of an understanding of the design stance. Kelemen contrasted the original function of objects – artifacts and body parts – with alternative uses of these objects. The alternative uses occurred by accident – once or many times, or intentionally – once or many times. Kelemen asked 4- and 5-year-olds what they thought the objects were for. She found that in all but the many-times-intentionally condition, both for artifacts and body parts, children do not differ from adults and choose the original function as what the objects were for. However, when an object is intentionally and consistently used for a purpose other than that which it was designed to perform, children differ from adults in their willingness to accept this function as the object's function. Unfortunately, in all but the many-times-intentionally condition, it was unclear whether children were invoking the intended function of the creator or just a function that was desirable (accidents have a negative connotation, and the one time intentional alternative function was said to never happen again, also suggesting something not desirable). Thus, in the condition where there was true conflict between the original function and an alternative function such that both seemed desirable, preschoolers were no longer sure which of them determines what the artifact is for.

Keil (1992) suggested that kindergartners apply the design stance when looking

for explanations for biological properties. Five- and 7-year-olds were shown a plant (a biological kind) and an emerald (non-biological natural kind) and were asked to choose which of two answers better explains why they are green. The first was functional/teleological – they are green because it is better for them and it helps there to be more of them. The second was reductionist – because there are tiny parts in them which cause them to be green. Second graders preferred the functional explanations for the plants and the reductionist explanations for the emeralds. Kindergartners showed no preference, belying Keil's conclusion. In a second experiment Keil contrasted a prickly plant with a prickly mineral and told the children that only one is prickly because it is good for it. The children were asked to pick which one was prickly because it was good for it. Keil reports that kindergartners chose the plant over the mineral.

While providing evidence for kindergartners finding explanations in terms of purposes more appropriate for plants than for inanimate objects, these results are inconclusive with respect to children's understanding of the design stance. The explanations the children had to chose from included expressions such as 'good for it', and 'better for it'. It is probably the case that these expressions are rarely used with minerals or barbed wire. They are more commonly used in conjunction with plants and might have been chosen by the children simply on this basis.

Indeed, using neutral phrasing, Kelemen (1999b) found that 7- and 8-year-olds prefer teleological explanations for both biological and non-biological natural kinds. For example, when asked why some pictured rocks are pointy, first and second graders prefer 'so that animals won't sit on them and smash them'(teleological) over 'because little bits of stuff piled over a long time'(physical). It is only by fourth grade (10-year-olds) that children make more adult-like choices, preferring teleological explanations for biological kinds and rejecting them as explanations for non-biological natural kinds.

In sum, we take the currently available results to suggest that preschool children have not yet constructed the design stance. An alternative account of the results reviewed above cannot be conclusively ruled out – they do understand the stance, but idiosyncratic factors make each of the tasks reviewed here difficult for young children. This is, of course, always possible.

What of the 6-year-olds? They succeed on the task; does that mean they understand the design stance? Not necessarily. This task does not provide an operational definition of understanding the design stance. Failure is good evidence they don't, but something less than the full design stance as we have laid it out could underlie success. The 6-year-olds may know that the person who makes the artifact gets to say what it is and what it is called, but unlike the adults, they may not know why the creator has this prerogative. The creator has this prerogative because he or she made an artifact with the necessary features to fulfill a certain function, or as Bloom (1996) would have it, because he or she successfully created the artifact with the intention that it belong to that kind. However, using a simple rule such as 'the person who makes an artifact gets to name it' may suffice for succeeding on the present task. Such an understanding, which does not include the notion of design, is far from a full understanding of the stance.

Indeed, German and Johnson (1997) suggest that 5-year-olds use this simple rule. Given their finding that children have no preference for the original function over the current function in saying what an item is for, they looked to see what guides children's naming of artifacts. Five-year-olds were told about someone who made an artifact and called it a Tog and about another person who saw the artifact and called it a Nif. Children were asked what the item was – a Tog or a Nif. In contrast to their response pattern when judging what an item was for, when naming the item, the 5-year-olds' judgments were consistent with who made it. This suggests that they may be applying the rule that he who makes an artifact gets to name it.

A similar consideration may bear on the interpretation of two aspects of the 4-year-old results – the asymmetrical order effect, and the barely above chance performance (66%) in Experiment 2 – to suggest that they may have a glimmering of the distinction between original function and current function. The asymmetrical order effect showed that it is not the case that children simply based their kind judgment on the first mentioned function. They did so only when the first mentioned function was the original function (81% in Experiment 2, 79% in Experiment 3) and not when the first mentioned function was the current function (50 and 44%, respectively). These data suggest that at least some 4-year-olds may be beginning to be sensitive to the distinction between originally intended function and current function – as does the fact that the above chance performance in Experiment 2 was achieved by 4-year-olds who were selected by their ability to remember the information in the task based on this very distinction. It is certainly possible that some 4-year-olds have begun to construct the design stance. It is also possible, as suggested above, that a sensitivity to original function may be due to an understanding that is less than a full understanding of the design stance. Thus, a rule such as 'the person who makes an artifact gets to name it', or a belief that kind stays constant through the whole existence of an artifact may focus attention on origin and lead to such sensitivity. However, the fact that 4-year-olds did not appeal to origins or feasibility to justify their categorization judgments favors the weaker of these interpretations.

Although appeals to the principle that the person who makes an artifact gets to name it may contribute to the success of the 6-year-olds in Experiment 3, it is also possible that 6-year-olds (and even some 4-year-olds) are in the midst of constructing the full design stance. Indeed, acquiring this heuristic rule is most probably part of the process of mastering the full stance. Unlike the 4-year-olds in Experiments 2 and 3, the justifications of the 6-year-olds included substantial appeals to origin and to feasibility, like those of adults. Also, it is around the age of 6 that children consistently start relying on the functional features of an artifact as opposed to its perceptual features in their kind judgments (Gentner, 1978; Keil, 1989; Landau et al., 1998; Tomikawa & Dodd, 1980) and it is at this age that promiscuous teleology begins to wane, at least in some circumstances (Kelemen, 1996; Piaget, 1929).

In sum, the currently available data suggest that the design stance is not part of core knowledge; it is acquired relatively late, beyond the preschool years. In this way, it is like late emerging framework theories such as vitalist biology (Carey, 1985, 1995, in press; Inagaki & Hatano 1996; Slaughter et al., 1999) and a particu-

late theory of matter (Au, 1994; Carey, 1991; Piaget & Inhelder, 1974; Smith, Carey, & Wiser, 1985).

How are new explanatory stances or framework theories constructed? Carey (in press) discusses a variety of bootstrapping mechanisms that are involved in the process, and discusses their role in the construction of a vitalist biology and in the construction of a theory of matter in which *weight* and *density* are differentiated. We do not have a well worked-out proposal for the construction of the full design stance, but offer the following observations.

First, preschool children understand many of the elements of the stance – they understand people's actions in terms of their intentions, they analyze objects, both artifacts and natural kinds, in terms of functions to which they may be put, and they distinguish between artifacts and natural kinds in terms of the fact that people make artifacts but not natural kinds. The construction and entrenchment of the design stance consists of working out the causal relations among these elements. Second, developments in other domains may serve to highlight, through analogy (a paradigm bootstrapping process, see Nersessian, 1992), the importance of origins in explanatory structures and in essentialist understanding of kinds. The years 5 through 8 witness a reorganization of understanding of animal kinds in terms of their origins (Johnson & Solomon, 1997; Keil, 1989; Solomon, Johnson, Zaitchik, & Carey, 1996; Springer & Keil, 1989). This development may enhance attention to the origin of artifacts as the child works out the design stance – the explanatory structure that supports inference-to-best-explanation judgments concerning an artifact's very existence, its kind, its properties and its functions.

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Appendix A. Scenarios from Experiment 3

A.1. Scenario A

See this woman? She made this thing. Now this woman wanted something to hit baseballs with in the park. But she didn't have anything to do that with. So you know what? She decided to make something. So she went to the store and bought all the materials she needed so she could make something to hit baseballs with. She then

went home and she spent the whole day carefully making something that was long and smooth. She said to herself: 'This is going to perfect for hitting baseballs with'. She then went to the park. But you know what? She forgot this thing on a bench next to her house.

But you know what? See this man? He's her neighbor. Now this man found this thing on the bench. He had been looking for something to roll out cookie dough with for a long time. He walked up to the bench and said: 'Hey, look what I found on this bench. It's exactly what I needed for rolling out cookie dough. It's long and smooth and just the right size'. So he picked it up and took it to his kitchen and he rolled out cookie dough with it.

So remember – this woman made this to hit baseballs with, and this man used it to roll out cookie dough. So can you tell me what this is: is it a baseball bat or a rolling pin? Now can you tell me why this woman made this? And what is this man doing with it?

A.2. Scenario B

See this man? He made this thing. Now this man wanted something to eat his dinner in the park. But he didn't have anything to eat on. So you know what? He decided to make something. So he went to the store and bought all the materials he needed so he could make something to eat dinner on. So he went home and he spent the whole day carefully making something round and flat. He said to himself: 'This is going to be perfect for eating dinner on'. So he then went to the park. But you know what? He forgot this thing on his kitchen table.

But you know what? See this woman? She's his sister. Now this woman found this thing on the table. She had been looking for something to throw back and forth in an outdoor game with her friends for a long time. She walked up to the table and said: 'Hey, look what I found on this table. It's exactly what I needed for throwing back and forth in an outdoor game. It's round and flat and just the right size'. So she picked it up and took it to the park and threw it back and forth with her friends.

So remember – this man made it to eat dinner on and this woman used it to throw back and forth in an outdoor game. So can you tell me what this is: is it a plate or a Frisbee? Now can you tell me why this man made this? And what is this woman doing with it?

A.3. Scenario C

See this woman? She made this thing. Now this woman wanted to have tea in her garden. But she didn't have anything to make it in. So you know what? She decided to make something. So she went to the store and bought all the materials she needed so she could make something to make tea in. She then went home and she spent the whole day carefully making something with a spout and handle. She said to herself: 'This is going to be perfect for making tea in'. So she then went outside to the garden. But you know what? All of a sudden she had to leave the house so she left this thing on the table outside.

But you know what? See this man? He's her neighbor. Now this man found this

thing on the table. He had been looking for something to water flowers in his garden for a long time. He walked up to the table outside and said: 'Hey, look what I found on this table. It's exactly what I needed for watering the flowers in the garden. It has a spout and a handle and it's just the right size'. So he picked it up and watered the flowers in his garden with it.

So remember – this woman made this to have tea in her garden and this man is using it to water flowers. So can you tell me what this is: is it a teapot or a watering can? Now can you tell me why this woman made it? And what is this man doing with it?

A.4. Scenario D

See this man? He made this thing. Now this man wanted to eat some cereal in his garden. But he didn't have anything he could eat in. So you know what? He decided to make something. So he went to the store and bought all the materials he needed so he could make something he could eat cereal in. He then went home and spent the whole day carefully making something round and deep. He said to himself: 'This is going to be perfect for eating cereal in'. But you know what, all of a sudden he had to leave the house so he left the thing he made on the kitchen table.

But you know what? See this woman? She's his sister. She found this thing on the table. Now this woman had been looking for something to wear on her head so she wouldn't get hurt when she was riding her bicycle. She walked up to the table and said: 'Hey, look what I found on this table. It's exactly what I needed for wearing on my head so I don't get hurt. It's deep and round and it's just the right size'. So she picked it up and wore it on her head while she was riding her bicycle.

So remember – this man made this to eat cereal in and this woman is wearing it on her head so she won't get hurt. So can you tell me what it is: is it a bowl or a helmet? Now can you tell me why this man made this? And what is this woman doing with it?

References

Au, T. (1994). Developing an intuitive understanding of substance kinds. *Cognitive Psychology*, *27*, 71–111.

Baron-Cohen, S. (1995). *Mindblindedness: an essay on autism and theory of mind*. Cambridge, MA: MIT Press.

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

Brown, A. (1989). Analogical transfer in young children: analogies as tools for communication and exposition. *Applied Cognitive Psychology*, *3*, 275–293.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Carey, S. (1991). Knowledge acquisition: enrichment or conceptual change? In S. Carey, & R. Gelman (Eds.), *The epigenesis of mind: essays in biology and cognition* (pp. 257–291). Hillsdale, NJ: Erlbaum.

Carey, S. (1995). On the origin of causal understanding. In S. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition* (pp. 268–308). Oxford: Clarendon Press.

Carey, S. (in press). Sources of conceptual change. In E. K. Scholnick, K. Nelson, S. A. Gelman, & P. Miller (Eds.), *Conceptual development: Piaget's legacy*. Hillsdale, NJ: Erlbaum.

Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press.

Gelman, S. A., & Coley, J. D. (1991). Language and categorization: the acquisition of natural kind terms.

In S. A. Gelman, & J. P. Byrnes (Eds.), *Perspectives on language and thought: interrelations in development* (pp. 146–196). Cambridge, MA: Cambridge University Press.

Gelman, S. A., & Kremer, A. (1991). Understanding natural cause: children's explanations of how objects and their properties originate. *Child Development*, *62*, 396–414.

Gentner, D. (1978). A study of early word meaning using artificial objects: what looks like a jiggy but acts like a zimbo? *Papers and Reports on Child Language Development*, *15*, 1–6.

Gergely, G., Nadasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, *56*, 165–193.

German, T., & Johnson, S. C. (1997). *Children's knowledge artifacts: goals, agents and origins*. Paper presented at the biennial meeting of the Society for Research in Child Development, Washington, DC.

Hall, D. G. (1995). *Artifacts and origins*. Unpublished manuscript.

Inagaki, K., & Hatano, G. (1996). Young children's recognition of commonalities between animals and plants. *Child Development*, *67*, 2823–2840.

Johnson, S. C., & Solomon, G. E. (1997). Why dogs have puppies and cats have kittens: the role of birth in young children's understanding of biological origins. *Child Development*, *68*, 404–419.

Keil, F. C. (1986). The acquisition of natural kind and artifact terms. In W. Demopoulos, & A. Marras (Eds.), *Language learning and concept acquisition* (pp. 133–153). Norwood, NJ: Ablex.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.

Keil, F. C. (1992). The origins of an autonomous biology. In M. R. Gunnar, & M. Maratsos (Eds.), *Modularity and constraints in language and cognition: the Minnesota Symposia on Child Psychology* (Vol. 25, pp. 103–137). Hillsdale, NJ: Erlbaum.

Kelemen, D. (1996). The nature and development of the teleological stance (Doctoral dissertation, University of Arizona, 1996). *Dissertation Abstracts International, 57(4),* 2897B.

Kelemen, D. (1999a). The scope of teleological thinking in preschool children. *Cognition*, *70*, 241–272.

Kelemen, D. (1999b). Why are rocks pointy? Children's preference for teleological explanations of the natural world. *Developmental Psychology*, *35*, 1440–1452.

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.

Kolstad, V. T., & Baillargeon, R. (1991). *Context-dependent perceptual and functional categorization in 10.5-month-olds*. Unpublished manuscript.

Landau, B., Smith, L. B., & Jones, S. (1998). Object shape, object function, and object naming. *Journal of Memory and Language*, *38*, 1–27.

Leslie, A. (1994). TOMM, ToBy and Agency: core architecture and domain specificity. In L. Hirschfeld, & S. Gelman (Eds.), *Mapping the mind: domain specificity in cognition and culture* (pp. 119–148). New York: Cambridge University Press.

Malt, B. C., & Johnson, E. C. (1992). Do artifact concepts have cores? *Journal of Memory and Language*, *31*, 195–217.

Matan, A. (1997). *Preschoolers' understanding of the design stance*. Poster presented at the biennial meeting of the Society for Research in Child Development, Washington, DC.

McCarrell, N. S., & Callanan, M. A. (1995). Form-function correspondences in children's inference. *Child Development*, *66*, 532–546.

Medin, D., & Ortony, A. (1989). Psychological essentialism. In S. Vosniadu, & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 179–195). Cambridge: Cambridge University Press.

Nersessian, N. J. (1992). How do scientists think? Capturing the dynamics of conceptual change in science. In R. N. Giere (Ed.), *Cognitive models of science. Minnesota studies in the philosophy of science* (Vol. 15. pp. 3–44). Minneapolis, MN: University of Minnesota Press.

Piaget, J. (1929). *The child's conception of the world* (J. Tomlinson, & A. Tomlinson, Trans.). London: Routledge & Kegan Paul.

Piaget, J., & Inhelder, B. (1974). *The child's construction of quantities: conservation and atomism* (Arnold J. Pomerans, Trans.). New York: Basic Books. (Original work published 1942).

Rips, L. J. (1989). Similarity, typicality, and categorization. In S. Vosniadu, & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 21–59). Cambridge, MA: Cambridge University Press.

Slaughter, V., Jaakkola, R., & Carey, S. (1999). Constructing a coherent theory: children's biological

understanding of life and death. In M. Siegel, & C. Peterson (Eds.), *Children's understanding of biology and health*. Cambridge: Cambridge University Press.

Smith, C., Carey, S., & Wiser, M. (1985). On differentiation: a case study of the development of the concepts of size, weight and density. *Cognition*, *21*, 177–237.

Solomon, G. E. A., Johnson, S. C., Zaitchik, D., & Carey, S. (1996). Like father, like son: young children's understanding of how and why offspring resemble their parents. *Child Development*, *67*, 151–171.

Springer, K., & Keil, F. (1989). On the development of biologically specific beliefs: the case of inheritance. *Child Development*, *60*, 637–648.

Tomikawa, S. A., & Dodd, D. H. (1980). Early word meanings: perceptually or functionally based? *Child Development*, *51*, 1103–1109.

Wellman, H., & Gelman, S. (1992). Cognitive development: foundational theories of core domains. *Annual Review of Psychology*, *43*, 337–375.

Wellman, H., & Gopnik, A. (1994). The theory theory. In L. Hirschfeld, & S. Gelman (Eds.), *Mapping the mind: domain specificity in cognition and culture* (pp. 257–293). New York: Cambridge University Press.