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PAPER

Teleo-functional constraints on preschool children's reasoning about living things

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Abstract

These studies explore the degree to which preschool children employ teleological-functional reasoning – reasoning based on the assumption of function and design – when making inferences about animal behavior. Using a triad induction method, Study 1 examined whether a sensitivity to biological function would lead children to overlook overall similarity and instead attend to relevant functional cues (in the presence of overall dissimilarity), as a basis for generalizing behavioral properties to unfamiliar animals. It found that, between 3 and 4 years of age, children, with increasing consistency, attend to functional features rather than overall similarity when drawing inferences about animal behavior. Children's ability to describe the relevance of functional adaptations to animal behavior also increased with age. Study 2 explored whether Study 1 findings might result from stimulus biases in favor of the function-based choice. It found that children's attention shifted from functional features to overall similarity when generalizing labels rather than behaviors with the same triads. These results are discussed in relation to the development of biological knowledge.

Introduction

Teleological-functional reasoning – reasoning that is based upon the assumption of function and design – is a central aspect of adult biological thought. For example, when seeing a novel anatomical feature on an animal for the first time, the first question an adult will usually ask is 'what's that for?' This assumption of function not only helps to constrain adults' hypotheses about the nature and behavior of unfamiliar animals but also their role in the larger context of the natural world since animals that are functionally specialized to perform certain activities (e.g. eat meat or swim) behave in ways that have consequences for other organisms in their ecological system (e.g. herbivores, other acquatic life). Teleo-functional reasoning therefore supports rich induction and theory-formation about the domain of living things (see Dennett, 1987; Keil, 1995; Kelemen, 1999a, 1999b; Mayr, 1982).

Given its importance in adult biological reasoning (e.g. Allen, Bekoff & Lauder, 1998; Dawkins, 1986; Gould & Lewontin, 1978; Mayr, 1982), there has been increasing interest in the role teleo-functional thinking might play in children's understanding of the natural world. Indeed, a growing body of research now suggests that, like adults, young children are biased to think about living things in functional terms. For example, Springer and Keil (1989) found that when judging the heritability of idiosyncratic parental physical properties (e.g. a pink rather than red heart), preschool children's responses were guided more by information about the properties' functional consequences than by more relevant information about the properties' congenital or acquired nature. A similar bias towards functional information has also been demonstrated in other contexts: Using explanation-choice methods, Keil (1992, 1995) and Kelemen (1999c, 2003a) have both found that when reasoning about the causes of biological phenomena, children have a precocious bias to explain natural properties and processes in terms of their 'self-serving' role in preserving an organism's well-being. For instance, when asked whether an unfamiliar kind of animal has a biological property (e.g. smooth skin) because of a purely physical process (e.g. 'they have smooth skin because it

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got stretched out tight across their bones') or because of its self-beneficial function (e.g. 'they have smooth skin so that they can move easily through the water') young children strongly endorse the latter teleo-functional explanation over the former physical account. Taken together, such findings have added increasing weight to the proposal that the teleo-functional tendency to view objects in functional terms may form part of the core of a first, possibly innate, biological theory (Atran, 1994, 1995; Keil, 1992, 1995; see also Carey, 1995; Hatano & Inagaki, 1994; Kelemen, 1999c, 1999d).

However, while the evidence thus far is suggestive, it should be noted that for the most part, these indications of a teleo-functional core to children's 'biological' intuitions have occurred in studies where function information about living things was either explicitly verbally offered or requested. The proposal that children's reasoning about living things is teleo-functionally constrained would consequently be substantially strengthened if it were shown that, when making inferences about animals, children spontaneously favor a function-based approach over an alternative strategy in contexts where functional information is not verbally explicit. In Study 1, we therefore presented children with such a context and explored the extent to which preschool children adopt a function-based, rather than an overall similarity-based strategy, when making inferences about the behavior of unfamiliar animals.

The decision to pit function information against global perceptual similarity was made because of the long debate within developmental psychology regarding the influence of general appearance on children's category formation. According to one view, young children are generally disposed to form categories on the basis of a directly perceived and unconstrained, overall similarity metric or 'original sim' (Keil, 1991). Examples of this 'holistic' categorization tendency are provided by numerous studies showing, for instance, that children will group together two objects based on their overall similarity to each other despite the existence of an identity relation between two other objects in the same stimulus set. Thus, in contrast to adults, preschool children will categorize together two shapes that are similar in size and color rather than placing together two shapes that are, for example, identical in size but different in color (Smith, 1989; see also Evans & Smith, 1988; Kelemen & Bloom, 1994; Kemler, 1983; Smith & Kemler, 1977; Werner, 1957).

According to another view, however, children's attention to perceptual information is, from early on, constrained by conceptual assumptions. With regard to research on natural kinds, one of the conceptual assumptions explored most has been category membership. For example, in classic research, Gelman and Markman (1986) found that when asked to generalize a non-obvious property from one of two line-drawn animals to a third line-drawn animal, preschool children attended more to shared category membership than overall similarity. Thus, when shown a flamingo and told 'this bird feeds its babies mashed up food' then shown a bat and told 'this bat feeds its babies milk', children reasoned that a third animal – a blackbird drawn to look very much like the bat – behaved like the dissimilar flamingo on the basis that they were both labeled as 'birds'. Children's tendency to adopt this strategy has been taken as evidence of an early essentialist belief that natural entities of the same category have deep, non-obvious similarities (e.g. common chemistry) that support strong inference (e.g. Gelman & Markman, 1986, 1987; Gelman, Coley & Gottfried, 1994; see Carey, 1995, for a different interpretation).

In the case of the Gelman and Markman study just described, the goal was to demonstrate that, under certain conditions, the influence of shared category membership is sufficiently strong that it can lead children to entirely disregard perceptual information when drawing inferences about natural kinds. In the present study, our question was rather different. Using actual photographs of animals rather than stylized drawings, we wanted to determine whether children's background beliefs about living things lead them to selectively attend to function-relevant perceptual information over other, more general, aspects of perceptual input when making inferences about biologically based behavior. The finding that children do selectively attend to function cues would support the idea that from early on children's categorization and reasoning about living things is guided by teleo-functional assumptions which – from an adult perspective – are particularly appropriate to the biological domain.

It should be added that the issue of whether young preschool children would spontaneously adopt a function-based approach to categorizing and making inductions about biological entities was very much an open question. McCarrell and Callanan (1995) have found that by 3 years of age, children certainly have the prerequisite knowledge of form–function correspondences to recognize, for example, that out of a pair of novel line-drawn animals, one with long kangaroo-like legs is more likely 'to jump high' than an identical animal with short stubby legs. However, to our knowledge, no study has examined whether children spontaneously use their understanding of these correlations to make broader predictions about an animal's lifestyle (e.g. its habitat, defensive strategy, its diet). Indeed, for the most part, specific explorations of children's tendency to categorize by functional information have almost exclusively focused on the artifact domain, largely because function plays such an obvious role in adults' construal of human-made objects such as chairs and shoes (Bloom, 1996; Keil, 1989; Kelemen, 1999b; Miller & Johnson-Laird, 1976; Rips, 1989; but see Malt & Johnson, 1992). Even within this domain – where function sometimes seems to define whole object identity – findings regarding children's approach to categorization have been equivocal. Repeatedly, experiments have suggested that, until approximately 6 years of age, children will ignore functional information to categorize novel artifacts on the basis of overall shape and global similarity (e.g. Gentner, 1978; Graham, Williams & Huber, 1999; Landau, Smith & Jones, 1998; Merriman, Scott & Marazita, 1993; Smith, Jones & Landau, 1996). The notable exception to this body of research are recent studies conducted by Kemler Nelson (e.g. Kemler Nelson, 1999; Kemler Nelson *et al.*, 1995; Kemler Nelson, Russell, Duke & Jones, 2000a; Kemler Nelson, Frankenfield, Morris & Blair, 2000b) which have shown that when an artifact's function is clearly causally related to its structure – that is, when the object looks unambiguously designed to perform only one particular activity – children as young as 2 years of age will lexically categorize on the basis of function rather than overall similarity (Kemler Nelson *et al.*, 2000a, 2000b). Even then, however, certain conditions must hold. To categorize in this manner, children younger than 3 to 4 years of age must have the chance to interact with the object and see it perform the relevant function: that is, they do not infer the function from simply viewing the structure alone (Kemler Nelson, 1999; Kemler Nelson *et al.*, 2000b; see also Corrigan & Schommer, 1984). Since we could not, for practical reasons, create conditions where children's awareness of biological function was heightened by interactions with the body parts of real animals and since we also wanted the current study to remain an implicit assessment of children's categorization approach – hence, a task in which similarity and functional relations were not explicitly pointed out – the youngest age group tested in the present study was therefore 3 years of age.

Specifically, the procedure that we employed was a triad induction method similar to that used by Gelman and Markman (1986). In the study, 3-, 4- and 5-year-old children were presented with information about the contrasting behavioral properties of two 'training' animals (e.g. a surgeonfish and a porcupine). They were then asked which of these properties was also true of a third, unfamiliar, 'test' animal (e.g. a porcupine box fish) – an animal that had overall similarity to one of the training animals (i.e. the surgeonfish) but was overall dissimilar to the other training animal (i.e. porcupine) with which it shared only a behaviorally relevant functional structure (i.e. spines). The question of concern was whether children would overlook global similarity and instead attend to relevant functional cues (in the presence of overall dissimilarity) as a basis for generalizing the biologically based behavioral property (its defensive strategy).

Study 1

Method

Participants

The participants were 16 3-year-old children (mean age: 3 years, 6 months; range: 2 years, 10 months to 3 years, 11 months; 12 boys, 4 girls), 16 4-year-old children (mean age: 4 years, 6 months; range: 4 years, 3 months to 4 years, 11 months; 6 boys, 11 girls) and 16 5-year-old children (mean age: 5 years, 5 months; range: 5 years, 0 months to 5 years, 11 months; 8 boys, 8 girls) attending various preschools and daycare facilities in the northeastern United States. A broad range of SES was represented. Children in the 3-year-old age group were presented with only a subset of the stimuli shown to 4- and 5-year-olds due to greater limitations on their attention span. Data collection with 3-year-olds was completed after data collection with the 4- and 5-year-old children. The procedure for the younger children was the same as that for the older age group bar some minor variations in attention maintenance strategies.

Materials

Children saw a series of picture card triads each consisting of three context-less animal photographs pasted on plain white card. Four- and 5-year-old children saw 12 picture triads while 3-year-olds saw a subset of six picture triads. In each triad set there were two 'training animals' (e.g. a shrew and a duck) plus a third 'test' animal (e.g. a platypus). The sets were constructed so that one of the training animals (e.g. shrew) shared overall perceptual similarity with the test animal (e.g. platypus) while the other training animal (e.g. duck) was dissimilar to the test but shared with it a specific similarity in the form of a functionally adaptive physical characteristic (e.g. billed beak).

While all of the triads maintained these similarity relationships, two types of picture sets were presented to each participant: In half the triads, the dissimilar training animal (e.g. duck) markedly differed in appearance from the test animal (e.g. platypus) because it also differed in category membership (e.g. bird versus mammal)

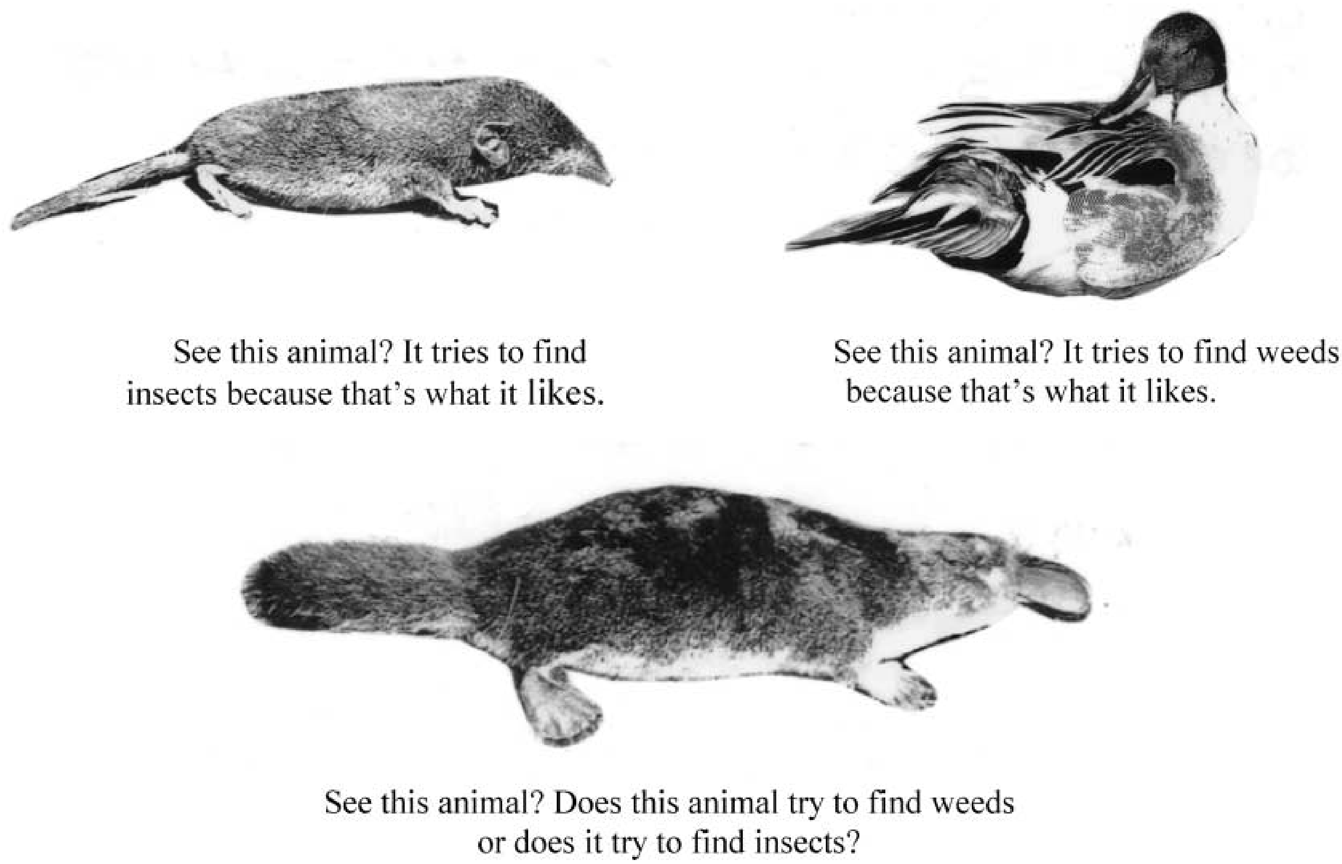


Figure 1 *Example of a 'between category' triad presented in Studies 1 and 2.*

while the other training animal (e.g. shrew) shared profound overall similarity with the test because it shared category membership (e.g. mammal and mammal). These triads were labeled 'between category' triads and were constructed to provide a particularly strong test of children's tendency to attend to functional parts because – while the category status of each animal was never explicitly labeled – the marked similarity relationship created by shared kind membership was thought to present a compelling challenge to generalization on a teleo-functional basis. In the remaining 'within category' triads, the training and test animals were all from the same basic category, for example, they were all birds or insects. Thus, in contrast to the between category triads, all of the training animals looked like the same kind of creature and differed only in their degree of similarity rather than their category. As a consequence, it was thought that children would be more likely to adopt a function-based approach with these within category triads since the overall similarity relations between two of the stimuli were not as striking as those in the between category triads. Examples of the different kinds of triads are provided in Figures 1 and 2.

Prior to testing, 12 naïve adult subjects independently validated the intended perceptual similarity relationships in each triad. Half the adults were asked to judge which animal was more similar to the test animal in each triad and half were asked to judge which animal was more dissimilar. Triads were excluded if there was less than 80% adult consensus on which of the training items was more overall similar or dissimilar to the test animal.

Procedure

Subjects were tested individually at a quiet area in their daycare center. The study took approximately 20 minutes to complete. For each trial, subjects were first presented with the training animals and told about a property of each without hearing the animal named (e.g. 'See this animal (shrew)? It tries to find insects because that's what it likes', 'See this animal (duck)? It tries to find weeds because that's what it likes'). After this, the test card was placed by the two training cards and the children were asked a forced-choice question (e.g. 'See this animal (platypus)? Does this animal try to find weeds or does it try to find insects?'). Children were then

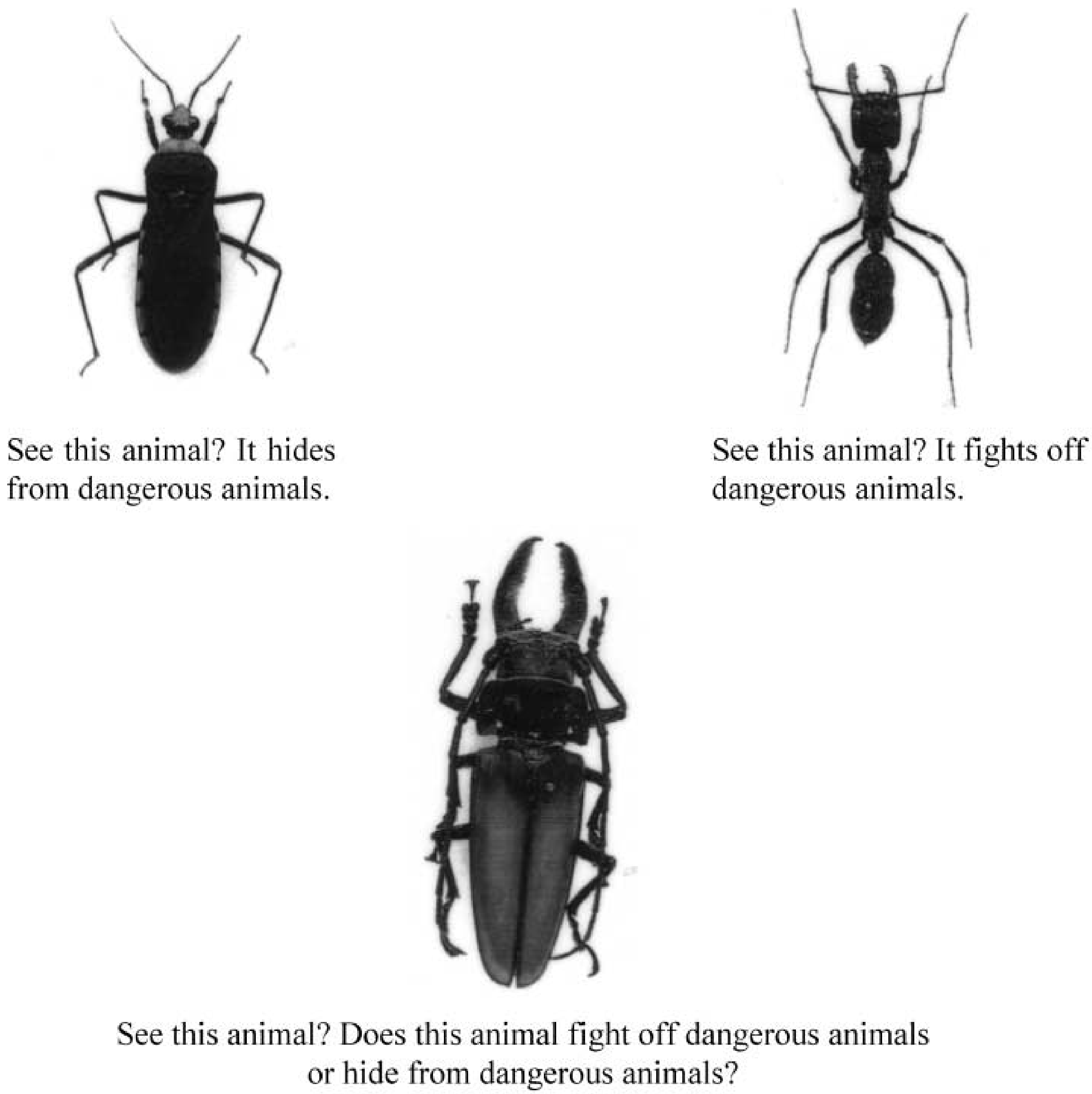
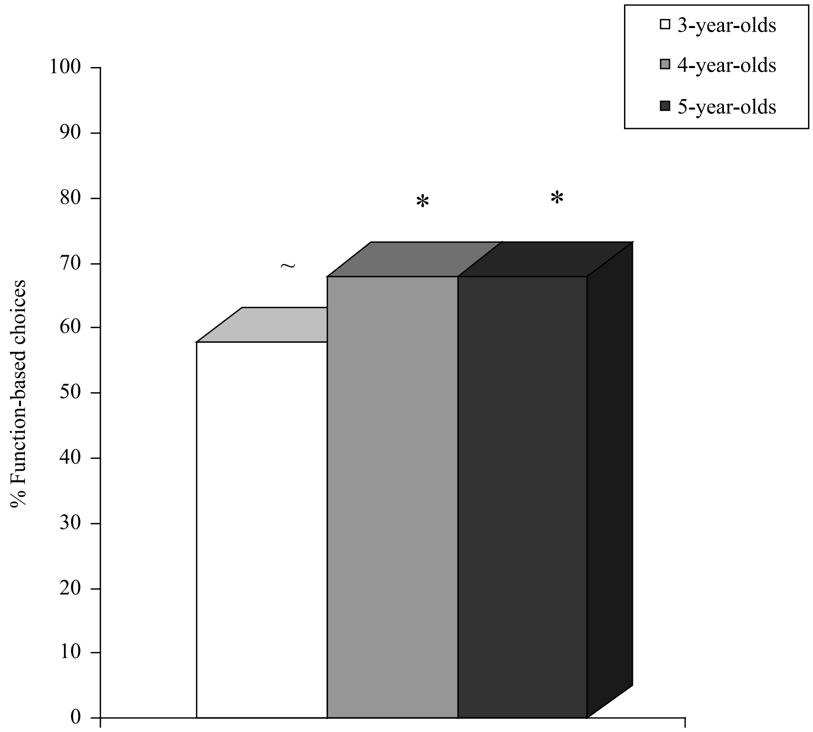


Figure 2 *Example of a 'within category' triad presented in Studies 1 and 2.*

asked to justify their responses. This step was taken in the knowledge that metacognitive and linguistic limitations would restrict young preschool children's ability to reflect upon and explain their strategy use. Nevertheless, it was of interest to see whether children's justifications spontaneously demonstrated any adult-like awareness of biological structure–function relations and also whether children's explanatory preferences would reflect any developmental trends, particularly given arguments that children's early reasoning about living things relies heavily on mental state reasoning and 'personification' (Carey, 1985; Inagaki & Hatano, 1987; Hatano & Inagaki, 1999). Triads were presented in one of four random orders. In half the trials, the dissimilar training animal was presented first and in half the trials, the overall similar animal was presented first.

Due to experimenter error, a triad that had only 58% adult similarity agreement (5 disagreements) was presented to 4- and 5-year-olds in the study. This triad was subsequently excluded from any analyses and was not presented to 3-year-olds. A further triad was excluded from analyses because 4- and 5-year-old children's justifications indicated that they were familiar with the test animal (a sea turtle) and were predominantly using specific background knowledge to answer the test question. Once again this triad did not form a part of the subset of triads presented to 3-year-olds. Analyses of 4- and 5-year-old children's strategies were therefore based on



Note: Notations indicate preferences differing from chance
$*p < .01$, two-tailed. $\sim p < .05$, one-tailed.

Figure 3 *Mean percentage of times that children adopted a function-based strategy in Study 1.*

their responses to 10 of the original 12 triads (5 within and 5 between category triads) while analyses of 3-year-olds' answers were based on their responses to all 6 of their original triads (3 within and 3 between category triads). The behavioral properties probed in the triads meeting the prerequisite perceptual criteria were of various types. Included were triads in which children predicted an animal's habitat (e.g. Does this animal spend time on the ground or go up in trees / spend time in the water?) in which the relevant functional parts included properties such as webbed feet or gripping toes; triads concerning a test animal's diet (e.g. Does this animal try to find weeds or does it try to find insects?) with relevant functional parts including properties such as billed beaks or gnawing teeth; finally, there were triads concerned with animals' defensive strategy (e.g. Does this animal fight off dangerous animals or hide from dangerous animals?) with functional parts including properties such as horns or spines. A greater proportion of triads probed for intuitions about habitat and defensive strategy simply because animal pictures depicting functional parts relevant to these behaviors were more available and these triads were also more likely to gain an acceptable adult consensus on the similarity relationships they presented. The triads are described in the Appendix.

Results

Figure 3 indicates the mean percentage of times children eschewed overall similarity and attended to functional characteristics as a basis for generalizing behavioral properties to the test animals. A 3 (age: 3-, 4-, 5-years of age) × 2 (triad type: within, between) mixed ANOVA was conducted on children's tendency to make a function-based choice by generalizing the behavioral property of the dissimilar training animal to the test animal. Proportion scores were used to control for the different number of items presented to 3-year-olds versus 4- and 5-year-olds.

The analysis found no effect of age, $F(2, 45) = 1.48$, $p > .05$, no effect of triad type, $F(1, 45) = 1.22$, $p > .05$ and no interaction, $F(2, 45) = 1.06$, $p > .05$. In other words, 3-, 4- and 5-year-old children were equally likely to make inferences based on functional attributes rather than overall similarity whether the dissimilar training animal category shared category membership with the test animal or not (3-year-olds, $M = 58\%$, 4-year-olds, $M = 68\%$, 5-year-olds, $M = 68\%$). However, further examination did reveal some indications of a developmental trend: While the tendency to select the function-based choice across all trials was significantly greater than chance for the 4-years-olds, $t(16) = 4.34$, $p < .001$, and

5-years-olds, $t(16) = 3.39$, $p < .004$, it was more marginal among 3-year-olds, $t(16) = 2.07$, $p < .06$, all t-tests two-tailed.

To understand the 3-year-old findings further, the data from individual participants were examined to see whether the marginal difference from chance occurred because 3-year-olds tended to split their decisions between the function-based choice and the overall similarity choice (with a couple of children occasionally favoring a function-based choice) or whether there were two groups of children: one showing a clear function-based induction pattern and the other showing an overall similarity pattern. The results provided tentative support for the idea that there were two groups of children. Eight (50%) of the children responded with an overall similarity choice in 50% or more of their trials while eight (50%) of the children responded with a function-based judgment in approximately 70% (67%) or more of their choices, $\chi^2(1, 15) = 1.0$, $p > .05$. By comparison, the tendency towards a function-based induction pattern was much clearer among the older age groups, with 75% of both 4- and 5-year-old children making function-based judgments in about 70% (67%) or more of their trials, both $\chi^2(1, 15) = 4.0$, $p < .05$.

Further analyses focused on children's justifications of their choices. Two people (both of them blind to predictions) coded responses into 6 exhaustive categories: (1) function-based justifications, (2) justifications based on general perceptual characteristics, (3) behavioral justifications, (4) mental state / personifying justifications, (5) general animal knowledge justifications, (6) other.

In order to be as stringent as possible about attributing children with a 'function-based' strategy, responses were only coded as function-based if children specifically referred to an animal's adaptive body part as the justification for their choice. Thus, for reasons of conservatism, justifications referring to a general physical property of an animal (e.g. height, weight) were not included in this category despite the fact that they could be interpreted as reflecting a sensitivity to structure–function relationships. Examples of function-based justifications are: 'Why do you think (this animal) fights when it's in danger (rather than hiding)?' 'because he has horns', '(because it has) sharp things', 'he has a needle'; 'Why do you think it goes up in trees / stays on the ground?' 'because it has wings', 'because he doesn't have sharp enough nails to climb a tree.'

In contrast to the function-based justifications, responses included in the coding category of 'general perceptual characteristics' did refer to general features such as height and weight. Examples are: 'Why do you think it fights / hides when it's in danger?' 'it's tall and big', 'it's small.' Also included in this category were justifications based on non-specific perceptual impressions (e.g. 'Why do you think it fights when it's in danger?' 'it looks like it', 'it looks like it would').

Regarding the remaining four categories of response, answers were coded as 'behavioral' justifications if children explained their judgment of an animal's habitat, diet or defense strategy by reference to another associated but different behavior or behavioral goal of the whole animal (e.g. seeking to reproduce, locomote, self-defend, gather food). For example, if in justifying their beliefs about a test animal's habitat (e.g. 'it goes up in the trees'), children made reference to the related issue of its eating behavior ('(he goes up in trees) so he can eat insects'), their answer was coded as a behavioral justification. Other examples include: 'Why do you think it goes up in trees?' 'so (it) can find birds and build (a) nest', 'so it can feed its birds', '(it) can't breathe (on the ground)'; 'Why do you think it's a water animal?' 'because it wants food (underwater)'.

'Mental state / personifying' justifications were those that invoked the animal's desire, human-like emotional state, or personal choice as a basis for justifying its behavior. Despite the possibility for overlap, these justifications were importantly distinct from the behavioral justifications. Within the class of behavioral justifications, children sometimes made use of mental state language or made anthropomorphic assumptions about an animal's motivations (e.g. 'it spends time in water because it *likes* to swim'). But critically the behavioral justifications were attempts to explain one aspect of an animal's life by reference to another kind of behavior.[1] In contrast, responses coded as mental state / personifying justifications were less elaborate: They were generally little more than assertions that the behavior selected in the forced-choice answer was primarily a consequence of the animal's desire, mental state or disposition. Examples are: 'Why do you think it goes up in trees?' '(it goes up in trees) because it likes it', 'because they love living

[1] Mental state language (e.g. 'wants', 'likes') occurred in a small percentage (approx 10%) of answers that were ultimately coded as behavioral justifications. The decision to code them as behavioral rather than mental state / personifying justifications was made because they represented a more mature chain of reasoning about the interrelationships that exist between different aspects of animal behavior (e.g. that habitat is connected to diet, reproduction) than any of the other explanations in the 'mental state' category. Furthermore, given their apparent greater sophistication, it was difficult to assess whether the use of mental state language in these cases was more an issue of speech pragmatics than actual intentional attribution. To ensure that there was no unfair bias created by these coding decisions, analyses were also run in which these kinds of behavioral justifications were recoded as mental state / personifying justifications. The pattern of results remained the same as that reported in the text.

Table 1 *Mean percentage of each justification type provided by 3-, 4- and 5-year-old children in Study 1*

	Function-based	Behavioral	Personification	General animal knowledge	General perceptual character
3-year-olds	10%	17%	13%	2%	2%
4-year-olds	36%	20%	14%	6%	1%
5-year-olds	38%	19%	4%	16%	4%
Overall mean	28%	18%	10%	8%	2%

there'; 'Why do you think it fights?' 'it likes to fight', '(it hides because) it's scared'.[2]

Answers coded as 'general animal knowledge' justifications were those in which perceived similarities to familiar animals or generalizations from familiar animal categories formed the basis for a response. Examples are: 'Why do you think it fights?' 'it looks like a deer', 'it's a beetle'; 'Why do you think this animal tries to find weeds?' 'it looks like a duck-cat'. Given the novelty of the specific test creatures the basis for the generalization was often inaccurate.

Finally, the 'other' category primarily contained 'don't know', non-responses and restatements (e.g. 'Why do you think it fights?' 'because he does'). It also contained the few 'uncodable' answers on which no coding agreement could be reached (e.g. 'Why do you think it hides?' 'he thinks it goes under him').

No category was created for overall similarity since no child ever made explicit reference to overall similarity relations between training and test animals as a basis for their justification. Reliability of agreement between the two coders was extremely high, Cohen's Kappa = 0.95 (Bakeman & Gottman, 1987). Coding disagreements between the two coders were resolved by having a third individual independently code all the data and reconcile conflicts on the basis of agreement between at least two coders (present in almost every case) or by discussion. The results are presented in Table 1.

Using proportion scores, a 3 (age) × 5 (all justification types excluding 'other' coding category) mixed ANOVA was conducted on children's explanations for their answers. The analysis found a main effect of age, $F(2, 45) = 10.20$, $p < .01$, a main effect of justification type, $F(4, 180) = 16.93$, $p < .01$, and an age by justification interaction, $F(8, 180) = 2.55$, $p < .01$. Post-hoc tests indicated that the effect of age occurred because, unsurprisingly, 4- and 5-year-old children ($M = 78\%$, 80%) provided a greater number of justifications than 3-year-olds ($M = 44\%$), Fisher's LSD, $p < .05$ in both cases. Post-hoc t-tests indicated that the effect of justification occurred because children were more likely to offer function-based justifications than any other kind of justification except behavioral ones, all significant t-tests, $p < .05$, two-tailed. Finally, the age by justification interaction occurred because two justification strategies underwent significant increases with age: 4- and 5-year-olds provided significantly more function-based justifications than 3-year-olds, $F(2, 45) = 5.69$, $p < .01$, Fisher's LSD tests, $p < .05$. Additionally, 5-year-olds were significantly more likely to justify responses based on general animal knowledge than 4-year-olds and 3-year-olds, $F(2, 45) = 4.52$, $p < .05$, Fisher's LSD tests, $p < .05$.

For the function-based strategy, developmental trends were also subtly revealed within each age group. Among 3-year-olds, a function-based strategy was actively favored over only one other strategy: an approach based on general perceptual characteristics, $t(15) = 2.45$, $p < .05$. Indeed, in general, 3-year-olds offered function-based, behavioral and mental state / personifying justifications with equal frequency. In contrast, 4-year-olds favored function-based explanation over all other justification types except behavioral justification (which they used to the same extent). They also favored behavioral justifications over all other responses except mental state / personifying justifications (which they invoked as frequently as 3-year-olds), all significant t-tests, $p < .05$. Turning to the oldest group of children, 5-year-olds continued to favor function-based justifications over all other justifications except behavioral ones. However, by 5 years of age, the use of personification was significantly reduced, with children drawing instead on general animal knowledge

[2] It could be argued that while implying a greater sensitivity to connections within the biological world, answers coded as behavioral justifications could equally have been coded as mental state / personifying justifications since they might have been instances of mental state reasoning where, for the most part, the mental state was not being explicitly marked (see Csibra & Gergely (1998) for a related discussion). While acknowledging this possibility, it is also important to acknowledge that the issue cannot be reliably determined: that is, it is equally possible that the behavioral justifications reflected a non-intentional understanding of the way animal behaviors relate to each other. Given this, the coding system adopted in the current study conservatively coded answers as behavioral versus mental state / personifying along the principled lines described in the text. As discussed in the General Discussion there were, however, indications that among younger children, behavioral justifications may have occurred in the context of a more psychological understanding of living things.

as often as behavioral justification, all significant *t*-tests, $p < .05$.

Finally, because 3-year-olds' tendency to favor function-based induction in the forced choice was more marginal, individual justification data were examined to gain further insight into the status of teleo-functional reasoning within this age group. As noted earlier, at the individual level, 50% of 3-year-olds showed a more function-based pattern of induction in the forced-choice and 50% tended towards an overall similarity pattern. Of interest was whether these two groups of children differed in their approach to justifying their choices. Analysis revealed that they did. 'Function-based' categorizers were the only 3-year-olds to ever provide any instance of a function-based justification while 'overall similarity' categorizers never did (63% vs. 0% of children). This finding lends weight to the idea that children in their third year begin to reliably draw on teleo-functional assumptions when reasoning about biologically based behavior even though a consistent ability to explicitly describe or reflect on their use of function-based induction remains limited at this age.

Discussion

The goal of Study 1 was to explore 3-, 4- and 5-year-old children's attention to functional information when making inductions about living things. Consistent with the hypothesis that young children's reasoning about living things is guided by teleological intuitions about function, the results reveal that, between 3 and 4 years of age, children increasingly demonstrate a strong tendency to eschew overall similarity, and preferentially focus on specific functional features, when making inferences about the biologically based behavior of animals. Furthermore, in the current study, the tendency to adopt a function-based approach was sufficiently robust that it was not undermined, even when competing with overall similarities that were particularly compelling, due to shared category membership between a training and test animal: As a result, no significant differences were found in children's responses to the 'between category' and 'within category' triads. This was true even for the 3-year-old age group whose preference for a function-based strategy was less marked but nevertheless evident. Taken together, these findings suggest that teleo-functional assumptions become increasingly influential as guides to induction about living things during the early preschool years.

Developmental trends were also found in children's ability to actively recognize and articulate the significance of function in the biological domain: 4- and 5-year-olds were more likely than 3-year-olds to explicitly identify the relevance of a functional adaptation to determining an animal's behavior. Indeed, patterns of justification within each age group revealed increases both in children's general capacities to consider and describe their own thinking, and their domain-specific insights into the biological domain. Specifically, on a significant proportion of occasions (56%), 3-year-olds were unable to justify their decisions, primarily giving 'don't know', restatements and non-responses when asked about their forced-choice intuitions. Furthermore, while there was some difference between sub-groups of 3-year-olds (i.e. 'function-based' vs. 'overall similarity' categorizers), in general, the justifications provided were very diverse in nature. That is, as a group, 3-year-olds were as likely to justify an animal's behavior in terms of its human-like mental states, as they were to explain it in terms of other kinds of animal behavior, or the presence of specially adapted functional parts. No one justification strategy predominated despite their performance on the implicit task, perhaps suggesting, consistent with theoretical proposals (e.g. Carey, 1985, 1995; see also Inagaki, 1997), that children's explicit understanding of the biological domain is not well differentiated from their understanding of the social behavioral domain and intentionality at this age.

In a striking shift of linguistic and metacognitive ability, by 4 years of age, the greater proportion of children (78%) were able to explain their responses. Furthermore, their justifications reflected the clear sensitivity to functional adaptation already demonstrated by their forced-choice responses. With these increases in explicit function-based reasoning, personification – while maintained as an explanatory strategy – took less precedence in children's overall pattern of explanation, with the greater balance of children's responses reflecting teleo-functional intuitions, and attempts to make coherent connections between different aspects of animal behavior. By 5 years of age, children's pattern of response differed once again. By this age, children's reliance on mental state / personifying justification was significantly reduced and a growing factual knowledge about living things was far more evident in children's responses. These trends in children's justifications support two ideas from prior theoretical work: (a) that personification is a strategy adopted in contexts where children have an absence of knowledge (e.g. Inagaki & Hatano, 1987) and (b) that children's explicit biological reasoning becomes increasingly differentiated from their intentional and social reasoning during the first decade of life (Carey, 1995; Inagaki, 1997). Indeed, taken together with the forced-choice responses, the justification patterns suggest that increasing factual knowledge of living things plays an important role in the gradual emergence of an explicit, differentiated, biology-specific theory of animal behavior – one that is, in part, founded on an underlying sensitivity to function.

To summarize, the present results show that from early on in the preschool years, children focus on functional parts, when they are making inferences about the biologically based behavioral properties of living organisms. This finding is consistent with the existence of a teleological-functional constraint on biological theorizing. Nevertheless, it is possible that another lower level explanation could explain the present pattern of results. Perhaps children were motivated to attend to functional parts in Study 1, simply because the 'part similarity' relationship represented in each triad was more perceptually salient than the 'overall similarity' relationship. In other words, perhaps the findings reflect nothing more than stimulus biases that would have led children to attend to part similarity relations regardless of the kind of categorization task they were conducting. Study 2 was performed to explore this possibility. Using exactly the same triad sets as in Study 1, Study 2 explored children's classification strategy when they were asked to generalize a different and also more culturally determined attribute: a category name. Since names are intended to pick out objects of the same kind and since – aside from the special cases presented in Gelman and Markman's (1986) classic study – overall similarity is usually a good predictor of basic category membership (see Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976), it was expected that children would attend to overall similarity rather than part similarity relations in Study 2, unless the perceptual salience explanation of Study 1 results proved accurate. Because young children are argued to be particularly 'perceptually bound' (e.g. Springer, 2001; also Madole & Oakes, 1999) and therefore more susceptible to the influence of perceptual salience than older children, Study 2 focused on classification strategies adopted by the younger age groups in Study 1: 3-year-olds and 4-year-olds.

Study 2

Method

Participants

The participants were 12 3-year-old children (mean age: 3 years, 7 months; range: 3 years, 0 months to 3 years, 11 months; 9 boys, 3 girls) and 10 4-year-old children (mean age: 4 years, 5 months; range: 4 years, 1 month to 4 years, 11 months; 4 boys, 6 girls) attending preschools in the northeastern United States. A broad range of SES was represented. None of the children in Study 2 had participated in Study 1.

Materials and procedure

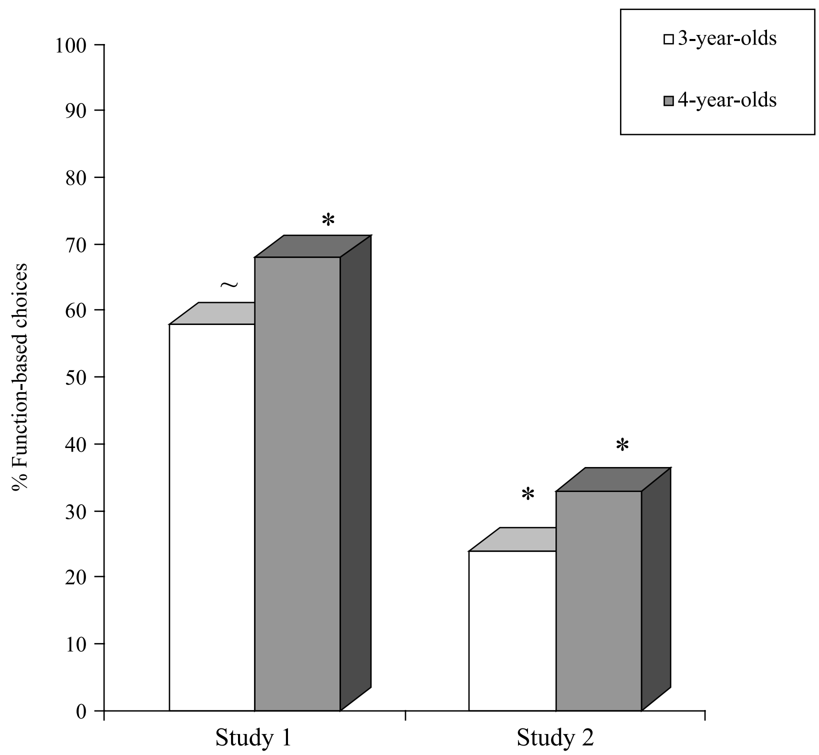
The materials used in Study 2 were the same picture triads that formed the basis of analyses in Study 1. Three-year-old children saw 6 triads (3 between category and 3 within category) while 4-year-old children saw 10 triads (5 between category and 5 within category). The general testing procedure was also the same as in Study 1. However, in contrast to Study 1, the property assigned to each training animal was a novel category name rather than a behavioral attribute. For example, when shown the triad in Figure 1, children were presented with the shrew and told 'See this animal? It is a fep.' They were then shown the duck and told 'See this animal? It is a cheadle.' Finally, they were shown the platypus test picture and asked 'See this animal? Is this animal a fep or a cheadle?' As in Study 1, it was expected that children's tendency to use an overall similarity strategy would be greater on the between category triads than the within category triads given the special salience of the overall similarity relationship existing between the 'same category' training animal and the test animal.

Triads were presented in one of four random orders. In half the triads, the dissimilar training animal was presented first and in half the triads the overall similar animal was presented first. The order in which a triad's training pictures were presented was also counterbalanced across subjects. Preliminary testing indicated that children in both age groups found it very difficult to justify why they had labeled an animal in a particular way. Responses to a follow-up question such as 'why do you think this animal is a cheadle?' generally elicited no response or justifications such as 'because it is'. Since these were not particularly informative, justification analyses were therefore not conducted for this study.

Results

Figure 4 indicates the mean percentage of times children attended to functional characteristics rather than overall similarity as a basis for generalizing novel category labels to the test animals. A 2 (age) × 2 (triad type) repeated measures ANOVA was conducted on children's tendency to make a function-based choice by assigning labels from the dissimilar training animals to the test animals. Proportion scores were used to control for the different number of items presented to 3- and 4-year-olds.

The analysis found no effect of age, $F(1, 20) = 1.67$, $p > .05$, but a significant effect of triad type, $F(1, 20) = 5.21$, $p < .05$. There was no age × triad type interac-



Note: Notations indicate preferences differing from chance
*$p < .01$, two-tailed. ~$p < .05$, one-tailed.

Figure 4 *Mean percentage of times that children adopted a function-based strategy in Study 1 and Study 2.*

tion, $F(1, 20) = .01$, $p > .05$. The effect of triad type occurred because children were more likely to adopt a function-based strategy with within category triads ($M = 37\%$) than between category triads ($M = 18\%$). With the latter they adopted an overall similarity strategy, on average, 72% of the time.

An analysis comparing 3- and 4-year-old children's responses on Study 1 and Study 2 was conducted to explore whether children were more likely to adopt a function-based strategy when generalizing biologically based behavioral properties than novel category labels. A 2 (experiment: Study 1, Study 2) × 2 (age: 3 years, 4 years) × 2 (triad type: within, between) mixed ANOVA was performed on children's tendency to make a function-based choice. The analysis revealed a main effect of experiment, $F(1, 50) = 57.38$, $p < .0001$, a main effect of age, $F(1, 50) = 4.12$, $p < .05$, and an effect of triad type, $F(1, 50) = 4.69$, $p < .05$. There were no interactions.

The effect of experiment occurred because 3- and 4-year-old children were more than twice as likely to use a function-based approach when generalizing a behavior ($M = 63\%$) than when generalizing a name ($M = 28\%$). The effect of age occurred because, in support of the idea that they are more 'perceptually bound', across experiments, 3-year-olds ($M = 57\%$) were more likely to categorize on the basis of overall similarity than 4-year-olds ($M = 46\%$). Finally, the effect of triad type occurred because, over both experiments, children more frequently used an overall similarity strategy with between category triads ($M = 56\%$) – where the test animal and function-based choice differed in both kind and appearance – than the within category triads ($M = 47\%$) where the dissimilarity was less marked.

Discussion

Study 2 was conducted to clarify whether children's tendency to make inferences on the basis of functional features in Study 1 was actually a result of the features' perceptual salience rather than children's adoption of a function-based approach to reasoning about animal behavior. Using the triads from Study 1, Study 2 found that when children were asked to generalize a category name rather than a biologically based behavior, they attended more to overall similarity relations than functional cues. This finding clearly indicates that the effects of Study 1 did not occur as a result of any inherent biases in the perceptual structure of the Study

1 triads since, across the studies, the perceptual relations that were salient to children shifted as a function of the kind of question they were considering. Together, the results from Studies 1 and 2 indicate that when they are predicting an animal's overt behavior, children selectively attend to functional adaptations, but when they are predicting an animal's category name and membership, they pay attention to overall similarity. Several factors might motivate children's attention to overall similarity when generalizing category names. First, the focus may result from an essentialist bias: From early on, children may believe that animals of the same category share common underlying properties (e.g. Gelman *et al.*, 1994; Gelman & Wellman, 1991). They may therefore attend to overall similarity when identifying members of the same category, because they assume that if animals look alike on the surface, they also probably look alike deeper down. Second, the attention to overall similarity may result from knowledge of language: Because the function of category labels is to pick out entities of the same kind, entities which are labeled alike also often look alike. Children's sensitivity to basic-level naming conventions therefore may be what drives their attention to overall similarity when applying novel labels to novel animals. Third, a combination of the essentialist bias and knowledge of naming conventions may provide an explanation of children's shift in strategy from Study 1 to Study 2.

In addition to the findings noted above, the present studies reveal a further developmental trend. Older preschool children were generally less likely than younger preschool children to attend to overall similarities when making categorization judgments of any variety. This trend is consistent with the notion that children's reasoning becomes less bound to superficial appearances with age. However, in the context of the current results, it is also important to note that even for the youngest age group, categorization based on overall similarity was *never* a global strategy that children applied indiscriminately. Three-year-olds were significantly more likely to adopt a function-based strategy when making inductions about animal behaviors (58%) than when making inductions about category labels (24%). From the earliest age tested then, there are clear indications that children recognize that functional adaptation predicts an animal's biologically based behavior in ways that it does not predict a more culturally determined property such as an animal's category name.

General discussion

Prior research has found that, when it is explicitly verbally presented, children treat function information as relevant to their judgments concerning the existence and potential heritability of biological properties (Keil, 1992, 1995; Kelemen, 1999c; Springer & Keil, 1989). The present studies offer an important extension of these earlier findings. The results show that, between 3 to 4 years of age, children, with increasing consistency, spontaneously attend to function when making inductions about the behavior of living things, even when that function information is implicit, and even when it is placed in competition with the kinds of compelling overall similarity relationships that result from shared category membership. Furthermore, by 4 years of age, children are increasingly able to reflect on and describe their attention to functional features when explaining why they believe animals do what they do. While this justification capacity was not as evident in younger children, it was present in individual 3-year-olds who were also more prone to consistent function-based categorization. In general, 3-year-olds acted like older children in attending more to function cues when drawing inferences about an animal's biologically based behavior than when inferring its category name. When considered along with earlier findings (e.g. Keil, 1992, 1995; Kelemen, 1999b, 1999c; Springer & Keil, 1989), the present results add substantial weight to proposals that teleo-functional intuitions play a central role in constraining young preschool children's reasoning and theory-building about living things.

However, while the results from the current studies provide a clear demonstration that young children's construal of animals is guided by a sensitivity to function, they also raise a number of additional questions. For example, what is the relative influence of a teleo-functional construal on children's thinking about living things? The issue arises for the following reason: In Study 1, the between category triads posed a greater challenge to a function-based categorization strategy than the within category triads because they presented an overall similar training animal (e.g. a weasel) that shared category membership with the test animal (e.g. an otter) and a functionally related training animal that did not (e.g. a bird). Despite the pronounced dissimilarity that lack of shared category membership created for the functionally related animal in the between category triads, Study 1 analyses found no effect of triad type; children were as likely to generalize on the basis of function cues in between category triads as in within category triads. This finding not only underscores the attractiveness of a function-based approach to children but also raises the provocative possibility that assumptions about functional design might actually influence children's reasoning about living things more than the powerful relationship of shared category membership (e.g. Gelman & Markman, 1986, 1987).

Before drawing such a conclusion, however, certain qualifications must be made. The goal of Study 1 was to explore the kinds of perceptual information that children might ordinarily weigh when making inductions about animal behavior. Because of this, we did not label the shared category membership of overall similar animals in between category triads since to do so would have established a substantial demand bias that could only have been countered by also having the experimenter explicitly point out part similarity relationships between animals.[3] This overt tutoring would have turned the study into something other than the implicit task that it was designed to be. Nevertheless, because we didn't explicitly tell children the different category relationships between animals in between category triads, we can't be sure that they inferred them. While the results of Study 2 strongly suggest that such an inference would have occurred – Study 2 children had a pronounced tendency to view overall similar animals as belonging to the same category – we can therefore only draw tentative conclusions about the comparative influence of function versus category membership based on Study 1 results. These suggest that when reasoning about animal behavior, teleo-functional intuitions influence children's inductions more than category membership intuitions. As to the broader influence of teleo-functional thought, it would be clearly premature to conclude that function matters more than category membership in all aspects of children's reasoning about animals. Numerous studies indicate that both children and adults assume animals of the same category share many underlying properties in common (Gelman & Markman, 1986, 1987; Gelman *et al.*, 1994; Wellman & Gelman, 1991). While attention to function cues rather than category membership does, arguably, provide a more reliable basis for determining whether two different animals both eat meat, both run away from danger, or both live in the water (see also McCarrell & Callanan, 1995), it is doubtful that such a strategy would be as useful for either children or adults when determining other non-obvious facets of biological life (e.g. what offspring or internal organs an animal is likely to have). In short, while the present results suggest that children might favor a teleo-functional approach over other approaches when reasoning about certain aspects of animal behavior, this does not mean that a function-based strategy generally predominates in young children's reasoning about all biologically based facets of living things. Further research is needed to establish the conditions under which a teleo-functional approach does take precedence for children and adults.

This last point leads to a further issue: As noted earlier, several theorists have proposed that teleological intuitions about function provide the partial core to children's first, autonomous, biological theory, in other words, a vitalistic or physiologically based construal of living things that is independent of any intentional or purely physical-causal construal of them (e.g. Atran, 1994, 1995; Keil, 1992, 1995; see also Carey, 1995; Inagaki, 1997). The present results certainly suggest that, by at least 4 years of age, children use their tendency to view objects in functional terms as a productive means of gaining insights into living things, actively recognizing the relevance of functional features to animal activities such as foraging and self-protection. Despite this, the question nevertheless remains: To what extent is evidence of a teleo-functional constraint on children's reasoning about animal behavior (albeit behavior that is biologically based from an adult perspective) truly evidence that young children possess a specifically 'biological' understanding of living things as vital organisms?

The answer to this question is that the existence of the teleo-functional bias is not, in itself, evidence of autonomous biological thought. This is because children's assessment that an animal with webbed feet spends time in the water because such feet are *for* swimming cannot be taken as a 'biological' insight unless there are indications that the function is understood in the context of larger biology-specific goals such as nourishment, reproduction, self-preservation and survival (Carey, 1995). In the absence of such an understanding, children's tendency to view structures as designed for functions that determine behavior could equally well represent a bias to view animals as 'quasi-artifacts' whose properties, like those of clocks and cars, have been somehow purposefully created to perform particular activities (see Kelemen, 1999a, 1999d). Indeed, one proposal as to the origin of teleo-functional intuitions is that they develop from an early privileged sensitivity to intentional goal-directed behavior. This view implies that design assumptions about the biological realm derive from the very same intentional source as the design assumptions about the artifact realm that children increasingly evidence from 3 years of age (e.g. Kelemen, 1999d, 2001, 2003b; also Carey, 1995; Inagaki, 1997).

However, having noted that evidence of a teleo-functional constraint is not, in itself, evidence of biological

[3] To have some sense of the bias that would have been introduced by explicit labeling of category membership in Study 1, consider the following example based on Figure 1: Experimenter: 'See this pompy (shrew)? It tries to find insects.' 'See this cheadle (duck)? It tries to find weeds.' 'Does this pompy (platypus) try to find weeds or try to find insects?' As the example should suggest, when an experimenter labels two particular animals with the same name, it suggests that he/she wants to draw attention to their commonality, providing an apparent cue to a 'correct' answer that any adult or child would find difficult to ignore.

understanding, there were indications in the current research that, by 5 years of age, children's teleo-functional intuitions were occurring in the context of an increasingly explicit biological awareness. Specifically, in Study 1, 4- and 5-year-old children's linguistic and metacognitive abilities were such that the two age groups did not differ in their willingness and ability to discuss their forced-choice responses. Nevertheless, their explanations subtly differed in kind. Both 4- and 5-year-olds offered a similar proportion of function-based and behavioral justifications, but these justifications co-occurred with a significantly higher proportion of mental state / personifying responses for 4-year-olds than for 5-year-olds, who instead drew far more frequently on references to general animal knowledge. The pattern is interesting because it suggests that among 5-year-olds, there is a growing understanding that mental states and personality characteristics are irrelevant to why an animal lives, eats, defends itself in the way that it does – an awareness that was also occasionally revealed in the content of some 5-year-old children's behavioral justifications (for example, the 5-year-old who explained that the reason one climbing animal lived up in the trees was 'to get away from predators so it could survive'). Findings such as these are consistent with theoretical proposals that children's explicit biological understanding of animals reorganizes to become autonomous from their psychological understanding of animals around 6 years of age (Carey, 1995; Hatano & Inagaki, 1999) and that the accumulation of animal knowledge may have much to do with this shift (Springer, 1999).

In conclusion, consistent with the existence of a teleo-functional constraint on reasoning about living things, the present results indicate that between 3 and 4 years of age, children, with increasing reliability, selectively attend to the functional properties of living things rather than overall similarity, as a basis for making inductions about animal behavior. Findings from Study 1 also suggest that, by 5 years of age, the teleo-functional assumptions influencing children's inductions are increasingly elaborated by biology-specific knowledge. Questions remain, however, concerning the origin of children's view that animal parts exist for purposes and its early development; for example, how does it relate to or build on infants' presumably atheoretical capacity to form object groupings on the basis of perceptual parts (e.g. Quinn & Eimas, 1996; Rakison & Butterworth, 1998; Rakison & Cohen, 1999) and their ability to note correlations between an object's structure and its actions (e.g. Madole, Oakes & Cohen, 1993; Madole & Cohen, 1995)? Furthermore, how is children's understanding of function in the biological domain related to their understanding of its role in the artifact domain given that the findings of the present studies and prior research suggest that, around 3 years of age, a sensitivity to function plays a significant role in guiding thinking about both domains (e.g. Keil, 1992; Kemler Nelson *et al.*, 2000a; see Kelemen, 1999d for further discussion)? While the present studies cannot answer these questions, they provide a fruitful basis for further research, since they provide some of the first clear evidence that, without adult prompting, very young preschool children use intuitions about function when theory-building about living things.

Appendix

Between category

*See this animal? (Siberian Weasel (OS)) It spends a lot of time on land.
See this animal? (Booby Bird (FS: webbed feet)) It spends a lot of time in the water.
See this animal? (Great Otter) Does this animal spend a lot of time on land or spend a lot of time in the water?

*See this animal? (Lizard (OS)) It is a land animal.
See this animal? (Eel (FS: webbing)) It is a water animal.
See this animal? (Newt) Is this animal a water animal or a land animal?

*See this animal? (Shrew (OS)) It tries to find insects.
See this animal? (Duck (FS: bill)) It tries to find weeds.
See this animal? (Platypus) Does this animal try to find insects or try to find weeds?

See this animal? (Red Wallaby (OS)) It stays on the ground.
See this animal? (Tree Frog (FS: toe grips)) It goes in the trees.
See this animal? (Bush Baby) Does this animal go up in the trees or stay on the ground?

See this animal? (Surgeonfish (OS)) It hides from dangerous animals.
See this animal? (Porcupine (FS: spines)) It fights off dangerous animals.
See this animal? (Porcupine Box Fish) Does this animal hide from dangerous animals or fight off dangerous animals?

Within category

*See this animal? (Assasin Bug (OS)) It hides from dangerous animals.
See this animal? (Black Ant (FS: pincers)) It fights off dangerous animals.

See this animal? (Longhorn Beetle) Does this animal fight off dangerous animals or hide from dangerous animals?

*See this animal? (Guam Rail Bird (OS)) It stays on the ground.
See this animal? (Hawk (FS: wings)) It goes up in the trees.
See this animal? (Starling) Does this animal stay on the ground or go up in the trees?

*See this animal? (Sheep (OS)) It hides when it is in danger.
See this animal? (Roe Deer (FS: antler/horns)) It fights when it is in danger.
See this animal? (Altai Mountain Goat) Does this animal fight when it is in danger or hide when it is in danger?

See this animal? (Mongoose (OS)) It is mainly a daytime creature.
See this animal? (Potto (FS: nocturnal eyes)) It is mainly a nighttime creature.
See this animal? (Mouse Deer) Is this animal mainly a daytime creature or a nighttime creature?

See this animal? (Tasmanian Devil (OS)) It tries to find small animals and insects.
See this animal? (Mole Rat (FS: gnawing teeth)) It tries to find roots and plants.
See this animal? (Woodchuck) Does this animal try to find roots and plants or does it try to find animals and insects?

Key: OS = Overall Similar, FS = Functionally Similar, * = Triads received by all age groups.

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