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Why do birds of a feather flock together? Developmental change in the use of multiple explanations: Intention, teleology and essentialism

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In two studies, 6–12-year-old children (Study 1: *N* = 58; Study 2: *N* = 38) and adults (Study 2: *N* = 22) rank ordered intentional, teleological and essentialist explanations for different behaviours of living-kind groups representing a range of biological kinds from plants to humans. Overall, humans elicited more intentional explanations, insects and plants elicited more essentialist explanations, and intermediate taxa, such as ungulates, elicited more teleological explanations. Children made fewer fine-grained taxonomic distinctions than adults, and the youngest children tended to reject essentialism. The 6–7-year-old children preferred to reason about living-kind behaviours from an intentional and teleological perspective; only towards the end of the elementary school years did children seem to incorporate a biological essentialism. Neither adults nor children were exclusively bound to a particular mode of explanation, but exercised 'causal flexibility' across different behavioural contexts.

As the coach herds his little league team onto the bus, afternoon shoppers flock to the mall for a sale. Meanwhile, a fearless youngster hangs like a monkey from the jungle gym in the playground. Each of these fairly common events seems simple to imagine, although none of them is true in a literal sense. Kahn (1997) argues that the ease with which we are able to detect commonalities among humans and other animals reflects a natural human tendency to affiliate with nature, the biophilia hypothesis. Given adults' ability to use their biological knowledge to draw systematic analogies between the behaviour of humans and other animals, some variant of this capacity is likely to be a feature in children's thinking as well. In two studies, we focus on the development of biological knowledge during the elementary school years and into adulthood. Specifically, we investigate whether, during this period, developmental change and/ or stability characterize the use of three causal explanations considered to be central to an understanding of the animate world: intention, teleology, and essentialism. In

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particular, we examine changes in the flexible use of these explanations in different behavioural contexts, which, we claim, is a critical component of the capacity to detect commonalities among living kinds.

To date, most of the research on children's reasoning about the biological world has focused either on the preschool years (e.g. Carey, 1985, 1999; Wellman & Gelman, 1998) or on older biology students (e.g. Brumby, 1984; Greene, 1990; Settlage, 1994) and adults in traditional cultures (e.g. Atran, 1995). We argue that it is important to describe the transition between the intuitive ideas of preschoolers and the folk biology of adulthood, as the nature of this transition has not been well characterized. This transition represents a critical shift as cultural- and school-based knowledge of the biological world is systematically incorporated into children's intuitive belief systems (Evans, 2000, 2001; Hatano & Inagaki, 1999). The naïve beliefs of the elementary school child represent both the elaboration of preschoolers' constructions and the early stages of the folk biology of the adult community. Moreover, characterizing the nature of the biological understanding of this age group has important implications for school curricula and other educational settings.

First, we briefly comment on what is known about the development of biological understanding, particularly of causal explanations of the animate world, during the school-age years. Then we elaborate on one feature, which we call causal flexibility: the flexible use of explanations in different behavioural contexts. We contend that causal flexibility is not only a characteristic of adult thinking but is likely to be present in the school-age years and, perhaps, earlier.

Intention, teleology, and essentialism

By 6 or 7 years of age, at least, there is some agreement that most children have constructed a kind of intuitive 'biology' informed by vitalistic (Carey, 1999; Inagaki & Hatano, 1993) or teleological premises (Keil, 1994; Kelemen, 1999b). Evidence suggests, however, that although an intuitive biology might be in place by the early school-age years it does not fully mature until much later; the reasoning of the 6- to 7-year-old, therefore, differs in an unspecified manner from that of older children's and adults' biological reasoning (Carey, 1996, 1999; Hatano & Inagaki, 1999; Inagaki & Hatano, 1993). In part this shift includes a refining of biological concepts such that some concepts become more differentiated, as with the concept of 'not alive' shifting to include distinctions between 'dead', 'inanimate', 'unreal', and 'non-existent' (Carey, 1999, p. 298). Other concepts coalesce: in particular, early ontologically distinct concepts of person, animal, and plant are increasingly likely to be classified under a superordinate category, living thing, and deemed to possess common biological capacities (Carey, 1999).

In the studies reported here we investigate the latter phenomenon by assessing whether there are age-related changes in the endorsement of different causal explanations for the behaviours of humans, species of increasing taxonomic distance from the human, and plants. Underlying the adult ability, described earlier, to detect commonalities among living kinds should be an appreciation of the extent to which general causal principles can reasonably be applied to the behaviours of different living kinds. The modes of construal we examine: intention, teleology and essentialism, are all implicated in children's reasoning about the world of living organisms (Wellman & Gelman, 1998).

Living organisms exhibit teleological characteristics in that they act purposefully; moreover, they appear to be 'designed' to function that way (Allen, Bekoff, & Lauder, 1998; Keil, 1994). Vitalism, with its emphasis on goal-directed behaviour (Morris, Taplin, & Gelman, 2000), may be an early form of teleological reasoning (Carey, 1999), or it could be the school-age child's transitional mode between the preschooler's intentional reasoning and the functional or mechanistic reasoning of older children and adults (Hatano & Inagaki, 1999; Inagaki & Hatano, 1993).

Although often conflated in the literature, teleological and intentional reasoning should in principle be separable processes (Keil, 1994). For example, complex artifacts, such as thermostats and cars, are often treated as if they are purposeful, without anyone believing that they are also intentional. Recent findings indicate that teleological reasoning is applied to natural inanimate entities (e.g. mountains, rocks), as well as to animate entities by preschool children (Kelemen, 1999a). This broad application of functional cause becomes more selective only towards the end of the elementary school years (10-year-olds), being applied almost exclusively to living kinds by Western-educated adults (Kelemen, 1999a, 1999b). Kelemen argues that this promiscuous use of teleological reasoning by preschool and young elementary school children may be an extension of the initially preferred intentional reasoning (1999a, 1999b). For adults, however, the inference of intentionality requires additional cues, such as similarity to the prototypical intentional entity, the human (Inagaki & Sugiyama, 1988); purposeful or goal-directed behaviour is necessary but not sufficient. In conclusion, it is not clear from the reported literature whether the reasoning of early elementary school children, at least, is sustained more by a type of teleological causality or by an intentional causality, or by both. It is likely, however, that intentional reasoning will be exhibited more by the 6–7-year-old than by the older child.

Essentialism is a catch-all term encompassing a variety of explanations that have at their core the idea that the behaviour or surface appearance of an organism is determined by its inner nature or essence. Gelman and her colleagues have documented preschoolers' readily invoked capacity to infer internal causes for animal motion, even when the animals were unfamiliar and carried by a person (e.g. Gelman, S., Coley, & Gottfried, 1994). These sorts of studies indicate that children grasp some notion of individual essence, at least to the extent that they appeal to an internalist or 'innards' principle (Gelman, R., Durgin, & Kaufman, 1995; Massey & Gelman, 1988) or to the concept of innate potential (Gelman, S. & Wellman, 1991). However, preschoolers' essentialism differs from that of adults, in that it does not incorporate mechanistic causality (Carey, 1999).

Causal flexibility

The hallmark of adult reasoning is, arguably, the capacity to shift preferences for a particular explanation depending on the available evidence and the nature of the behaviour and the target: called here causal flexibility (see also Keil, Levin, Richman, & Gutheil, 1999; Keil & Wilson, 2000). Nowhere is causal flexibility more evident than in the varied explanations given for human behaviours. Over the last 50 years informed explanations for behaviours as diverse as autism, alcoholism, schizophrenia, and even gender differences in maths achievement (e.g. Eccles, 1994) have ranged from largely psychological, to largely essentialist (i.e. genetic), to some synthesis of the two explanations. These shifts can be said to represent changes in preference for these explanations, informed by the latest research findings.

Most research to date has focused on the ages at which particular types of causal explanation are likely to be mastered, even though Keil suggests that these reasoning stances are not used in an all-or-none fashion (1994; Keil *et al.*, 1999). Central to Keil's thesis is the idea that foundational domains of knowledge (Wellman & Gelman, 1998), such as an intuitive biology or psychology, may be initialized by intricate combinations of abstract intuitive causal reasoning principles, such as teleology, intention and essentialism. None of these modes of construal, he argues, are uniquely tied to a domain, but they may be 'footholds' that allow humans to acquire more 'elaborated belief systems in ... a number of specialized domains', (Keil, 1994, p. 251). Teleological reasoning and essentialist reasoning, for instance, are not necessarily mutually exclusive and can be combined, creating a teleo-essentialist form of reasoning (Atran, 1995). For example, the apparent purposefulness of many animal behaviours, such as communication among bees, is thought to be innate and dependent on a collective genetic endowment (e.g. bee-essence). Alternatively, teleological explanations can be combined with intentional ones. Children might believe that 'birds flock together' because they like each other, which would be a straightforward psychological 'desire' explanation. Or they could believe that birds stay together for a purpose, because they *like* to be *safe* from danger, which would be a teleo-intentional explanation.

Preschool and early school-age children are potentially flexible in their thinking, in that they can discriminate between these explanatory modes (Gutheil, Vera, & Keil, 1998; Schult & Wellman, 1997), but, lacking the detailed biological and physical knowledge of older children and adults, younger children may use these explanations in a less discriminating fashion. Gutheil *et al.* (1998) argue that flexibility may be a crucial element in preschoolers' reasoning and they demonstrate that preschoolers can switch between biological and psychological explanatory modes, though they may default to the latter. Furthermore, such flexibility apparently increases with age; 8-year-olds and adults are more sensitive to different contexts than the younger children (Inagaki & Hatano, 1993).

In sum, we contend that it may be less interesting to ask whether individuals are exclusively wedded to a particular mode of explanation at specific ages, than to ask whether they exhibit causal flexibility: distinct preferences for different explanations across different behavioural contexts. We focus on two relatively neglected age-groups in this research area, the elementary school years and early adulthood.

In the first study reported in this paper, we asked child participants to judge why humans and other animals stay together in groups. We concentrated on the tendency to 'flock together', because it had two useful attributes that were central to our task. First, it functioned as a neutral behaviour that could conceivably elicit any of the above reasoning modes: intention, teleology, essentialism. Secondly, it was likely to focus participants' attention on the behaviour of the species as a whole, rather than on a single individual. In the second study, with adults and children, we extended the range of behaviours to include questions about individual behaviours, in particular, the reasons why animals and plants breathe and why they dream. In all studies, the range of biological categories was based on taxonomic distance from the human with the expectation that different taxons and behaviours would elicit different permutations and combinations of these reasoning modes (e.g. Inagaki & Sugiyama, 1988). Overall, the contexts we investigate vary along three dimensions, the kind of species represented, the nature of the explanation, and the kind of behaviour to be explained.

Although, like Gutheil *et al.* (1998), we sample different behavioural contexts, with our method participants can potentially display a greater degree of causal flexibility. Gutheil *et al.* (1998) found that preschool children demonstrated flexibility in the generalization of target behaviours (eat, sleep, etc.) from humans to different species depending on the condition. In each condition a fixed explanatory context was invoked: biological, psychological, or no context. In contrast, we ask participants to choose which of three explanations best describes why species of different kinds engage in different types of behaviour.

Our hypothesis was that older school-age children and adults would display causal flexibility, which would be demonstrated in differing patterns of explanation preference for different biological categories across different behaviours. Specifically, teleological and intentional explanations would become increasingly disassociated as a function of taxonomic distance of the targeted taxon from the human (Inagaki & Sugiyama, 1988). Moreover, older participants should apply an essentialist explanation to species as readily as young children apparently do to individuals. Although children's ability to use intention, teleology and essentialism to reason about animate behaviour has been documented (see Carey, 1985; Keil, 1994; and Gelman, S. *et al.*, 1994, respectively), less is known about the extent to which school-age children would employ causal flexibility. There should be an increase in flexible use of these explanations over the elementary school years as children acquire more detailed knowledge of the biological world (Carey, 1999; Keil *et al.*, 1999). There may also be changes in children's preferences for these explanations if they shift from a reliance on an intention-based reasoning stance to a more mechanistic or functional one. In the two studies reported in this paper, children's and adults' preferences for different reasoning stances were explored. We chose explanations that are considered characteristic of the three different reasoning stances: intention, teleology and essentialism, investigated in these studies (Wellman & Gelman, 1998).

STUDY 1

In Study 1, school-age children, 6–12 years of age, were asked: 'Why do these X's stay together?' for groups of humans, non-human mammals, insects and plants. We used an ambiguous version of the essentialist explanation (see Gelman, R., *et al.*, 1995; Gelman, S. A., *et al.*, 1994): 'They stay together because each one of them has the same things *inside*.' This was designed to elicit 'internalist' interpretations that vary according to participants' level of biological understanding in that it was deliberately content-neutral. As such, we hoped it would appeal both to older children (or adults), who might grant 'essential' causal power to genetics, and to 6-year-olds, who might grant essential causal power to an inchoate innards principle. This explanation is just one of several versions of an essentialist explanation, but one that seemed the most relevant given our concern (Gelman, S. & Hirschfeld, 1999).

Participants in both studies were asked to choose one explanation as the 'best' out of three possible explanations. The advantage of this method is that participants explicitly compared the three explanations when considering their choice. However, a potential shortcoming is that each explanation is not measured independently of the other two. To offset this shortcoming, analyses presented here focused only on the response chosen as the 'best'. Additionally, we believe this method is satisfactory, given findings from a set of preliminary studies (Poling & Evans, 1998) with children and adults.[1] We use the term 'explanation preference' guardedly to refer to participants' choices, without implying that participants would necessarily spontaneously generate these same explanations.

Method

Participants

The participants were 58 children ranging in age from 6 to 12 years, grouped in three non-overlapping age and grade ranges: (1) *6–7-year-old group*, $N = 20$ (13 males, 7 females), age range = 6.1 years to 7.1 years (mean age = 6.7 years), grade range = K–1; (2) *8–9-year-old group*, $N = 19$ (9 males, 10 females), age range = 7.8 years to 9.4 years (mean age = 8.5 years), grade range = 2–3; (3) *10–12-year-old group*, $N = 19$ (11 males, 8 females), age range = 10.0 years to 12.9 years (mean age = 11.2 years), grade range = 4–7. The majority of participants were Caucasian, two were African-American and two were multiracial.

All participants in Study 1 were interviewed in their after-school or summer programmes. The procedure lasted about 20 minutes. To verify interviewer reliability and to check the accuracy of transcripts, interviews with children were audiotaped with the written permission of the parents and the verbal permission of the child. Participation certificates and stickers or pencils were given to each child who participated in the study.

Materials and procedure

The same materials and procedure used in the preliminary studies were also used in the current study (Poling & Evans, 1998). One set of test cards, consisting of 12 different naturalistic photographs taken from natural history magazines and books, was used during the procedure. The photographs depicted four biological categories: humans, ungulates, insects and plants, with three exemplars from each category; all groups were portrayed in a neutral posture (standing, sitting, or lying down) in species-appropriate environments. To ensure that the human exemplars were unfamiliar, they were from three different non-western cultural groups. All human groups were pictured outdoors near their homes, where the homes ranged from concrete buildings to straw huts surrounded by forest. The nine animal cards consisted of pictures of ungulates (giraffes, elephants, zebras), insects (ants, bees, ladybirds), and plants (tulips, snowdrops and daffodils). To familiarize the participants with the procedure, three practice cards were used as a warm-up task, before the test cards were presented. The practice cards depicted large stationary land lizards, a cheetah chasing a group of impalas (called deer), and a group of children playing in water.

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[1] In two preliminary studies, we investigated 8-year-old children's and adults' explanation preferences for the grouping behaviour of humans and a range of non-human animals (see Poling & Evans, 1998). The findings in those preliminary studies are replicated in the studies reported here. In addition, we collected data from one adult sample using both the ranking method reported here and a rating method in which adults responded to each explanation independently. The results from these two methods were similar; however, pilot testing with younger children indicated that they found the ranking method easier. Therefore, we choose the ranking method for the two studies reported in this paper.

The cards were randomly presented to participants one at a time. Participants were asked for each picture 'Why do these X's stay together'. For each card, all three explanations were verbally presented one at a time in random order with computer-drawn visual mnemonics to represent each explanation (see Appendix). The three possible explanations were: intentional, 'They stay together because they *like* each other'; teleological, 'They stay together because they will be *safe* from danger'; essentialist, 'They stay together because each one of them has the same things *inside*'. For each picture, participants rank ordered the three explanations from the best to the worst, using the visual mnemonics. After participants had completed the procedure for the three practice cards, the 12 test cards were presented randomly, one at a time. The procedure was identical for practice and test pictures, but only test pictures were used in the analyses.

Scoring

For each picture, the explanation ranked as 'best' was given a score of 1. The remaining two explanations were given a score of 0. Thus, for each explanation for each picture, the possible range of explanation preference scores was 0–1, and for each explanation within each biological category, the possible range of explanation preference scores was 0–3. Across all trials, chance is 1: on each of three trials any one explanation could be chosen, at chance levels, one-third of the time. Mean explanation scores (mean 'best' scores) that differ significantly from chance are indicated by an asterisk on each of the figures.

Results

Overall analysis

Overall, the intentional explanation (like each other) was preferred for the humans, the teleological (to be safe from danger) for the ungulates and insects and the essentialist (same insides) was preferred for the plants. However, the 6–7-year-old children preferred the intentional explanation more and the essentialist explanation less than the 8–9- and 10–12-year-old groups.

The explanation preference scores for the children were analysed in a 3 (age group: 6–7-year-olds, 8–9-year-olds, 10–12-year-olds) × 3 (explanation: intentional, teleological, essentialist) × 4 (biological category: human, ungulate, insect, plant) mixed design analysis of variance (ANOVA), with explanation and biological category as repeated measures (see Fig. 1 for means and standard errors). Analyses indicated a significant main effect for explanation, $F(2,110) = 9.63$, $p < .0001$. Additionally, there was a significant explanation × age group interaction, $F(4,110) = 2.98$, $p < .02$, and a biological category × explanation interaction, $F(6,330) = 42.98$, $p < .0001$. More importantly, there was an explanation × biological category × age group interaction, $F(12,330) = 2.06$, $p < .02$. To clarify the nature of the interactions, analyses will be presented first for the intentional followed by the teleological and essentialist explanations across all biological categories, and then the explanation preference scores will be compared within each biological category.

Intentional explanation (like each other)

An age group (3) × biological category (4) ANOVA indicated significant main effects for age, $F(2,55) = 5.47$, $p < .007$, and biological category, $F(3,165) = 29.33$, $p < .0001$. Bonferroni *post hoc* comparisons indicated greater preference for the intentional explanation by the 6–7-year-old group as compared to both the 8–9-year-old ($p < .009$) and 10–12-year-old ($p < .005$) groups. In addition, the intentional explanation was applied more often to the humans than to any other biological category, by all age groups (all ps < .0001).

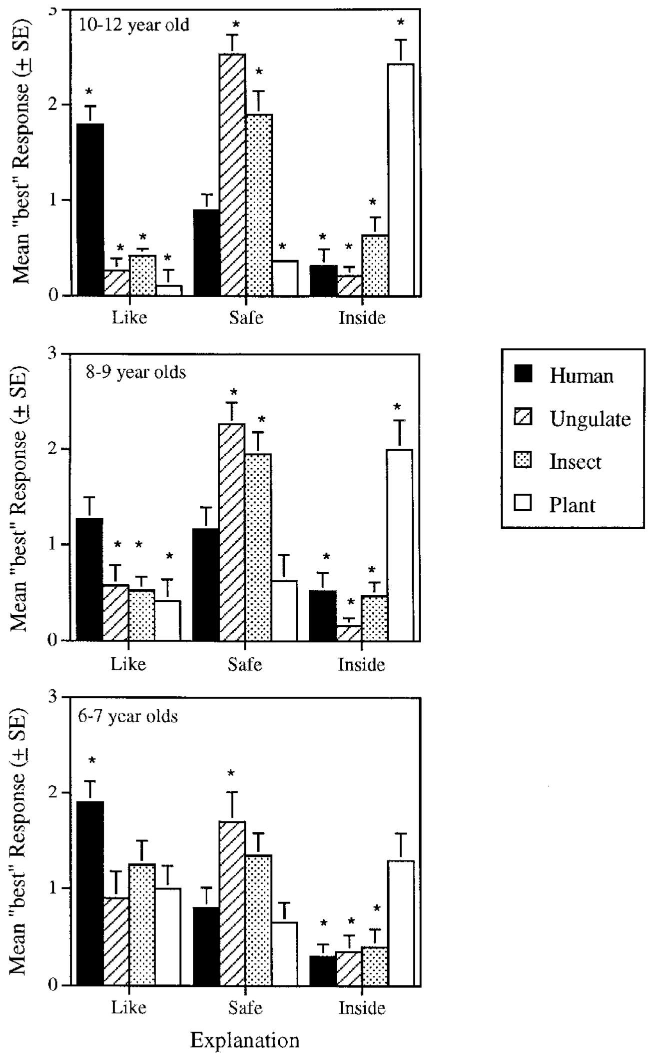

Figure 1. Study 1: Why do they stay together? Patterns of explanation preference across four biological categories for ages, 6 years to 12 years (*Chance= 1; p<.05)

Teleological explanation (safe from danger)

In a similar analysis, a significant main effect for biological category was found for the teleological explanation, $F(3,165) = 42.82, p < .0001$. Bonferroni *post hoc* comparisons indicated that all age groups preferred the teleological explanation more for ungulates than for any other category (all *p*s $< .008$). In addition, the teleological explanation was preferred more for insects than for humans or plants (all *p*s $< .0001$).

Essentialist explanation (same insides)

In a similar analysis, a significant main effect for biological category was found for the essentialist explanation, $F(3,165) = 54.24$, $p < .0001$. An age group × biological category interaction was also found, $F(6,165) = 2.67$, $p < .02$. Means indicate that the essentialist explanation was preferred more for plants than for any other category. Bonferroni *post hoc* comparisons indicated that the 10–12-year-old group preferred the essentialist explanation more for the plants than did the 6–7-year-old group ($p < .007$).

Human category

An age group (3) × explanation (3) ANOVA for the human category revealed a significant main effect for explanation, $F(2,110) = 20.67$, $p < .0001$. Bonferroni *post hoc* comparisons indicated that the intentional explanation was used more for the humans than was the teleological explanation ($p < .01$) and the essentialist explanation ($p < .0001$) collapsed across all age groups. In addition, the teleological explanation was used more for the humans than the essentialist explanation ($p < .01$). From Fig. 1, it can be seen that essentialism was rejected (significantly less than chance) by all age groups, whereas teleology was at chance. As in the second preliminary study, the 8–9-year-olds did not appear to distinguish between the teleological and intentional explanations for the human, both were at chance.

Ungulate category

In a similar analysis, a significant main effect for explanation was found for the ungulate category, $F(2,110) = 49.16$, $p < .0001$. Bonferroni *post hoc* comparisons indicated that the teleological explanation was preferred more for the ungulates than the intentional explanation ($p < .0001$) and the essentialist explanation ($p < .0001$) across all age groups.

Insect category

In a similar analysis, a significant main effect for explanation, $F(2,110) = 20.04$, $p < .0001$, and an explanation × age group interaction, $F(4,110) = 2.6$, $p < .05$, were found for the insect category. Bonferroni *post hoc* comparisons indicated that the teleological explanation was preferred more for the insects than the intentional explanation (*p*s $< .0004$) and the essentialist explanation (*p*s $< .002$) by the 10–12-year-old and the 7–9-year-old age groups. The 6–7-year-olds did not show a preference for any of the explanations for the insect category; they choose intention and teleology at chance levels and rejected essentialism.

Plant category

In a similar analysis, a significant main effect for explanation, $F(2,110) = 22.5$, $p < .0001$, and an explanation × age group interaction, $F(4, 110) = 3.3$, $p < .02$, were found for the plant category. Bonferroni *post hoc* comparisons indicated that the essentialist explanation was preferred more for the plants than the intentional explanation (*p*s $< .002$) and the teleological explanation (*p*s $< .006$) by the 10–12-year-olds and the 8–9-year-old age groups. The 6–7-year-old children, however, did not show a preference for any of the explanations for the plant category.

Discussion

Several age-related differences in elementary school children's preference patterns are seen in this study. As predicted, the 10–12-year-old children demonstrated an overall preference pattern that included fine-tuned discriminations between the explanations, targeting different taxonomic groups. For the 10–12-year-old children in this study, the essentialist explanation was favoured for the taxon most distant from the human, which was plants, and the intentional explanation was favoured most for the humans. Moreover, for both the ungulates and the insects, the 10–12-year-old children preferred a teleological explanation.

The 8–9-year-olds employed a range of explanations similar to those of the older age group, although their discriminations were less fine-tuned (see Fig. 1). However, for the plant category, both the 8–9-year-old and the 10–12-year-old groups endorsed essentialism at above chance levels, and this preference was greater for plants than for any other biological category. For the 6–7-year-old age group, there was no significant preference for any of the explanations for the plant category. Arguably, the patterns of preference for the 6–7-year-old children in this study reflect some uncertainty about plants at this age (see also Hickling & Gelman, 1995).

In addition, the 6–7-year-old children in this study showed a greater overall preference for the intentional explanation than did the older two groups. One possible reason for this endorsement is a preference for the more appealing visual mnemonic representing the intentional explanation (see Appendix). However, this is unlikely as an explanation, as neither insects or plants elicited a preference for intention in this age group. These results suggest an overall shift in children's preferences for intention and essentialism from the early to late elementary school years.

In summary, these analyses indicate that in general intention is preferred over teleology for the human category, and that in comparison with the two older elementary school-age groups, the 6–7-year-olds preferred intention at higher levels across all biological categories. The teleological explanation was preferred more for the ungulates than any other biological category by all age groups. Finally, the essentialist explanation was preferred more for the plants than for any other biological category by the two older age-groups.

STUDY 2

In Study 1, we investigated children's use of three explanations for a neutral grouping behaviour, which could plausibly be construed as psychologically or biologically caused. In Study 2 we examined the use of the same three explanations for this neutral grouping behaviour as well as two additional individual behaviours: breathing and dreaming. Breathing was judged to be a prototypical biological behaviour and dreaming a prototypical psychological behaviour (Flavell, Green, Flavell, & Groomsman, 1997; Miller & Bartsch, 1997). Whereas it may be questionable to ask children and adults about dreaming (or any psychological behaviour) for the plant category, we feel it adds an interesting dimension to the study. That is, asking children and adults why plants dream should force them to choose whichever explanation they would normally default to under ambiguous circumstances. If there is no default explanation, we can expect responses to the dream question for the plant category to be at chance.

Secondly, we altered the wording of the essentialist explanation. In Study 1, the youngest children (6–7 years old) seemed reluctant to choose the essentialist explanation, even for plants. This hesitancy could be due to young school-age children's difficulty in grasping the explanation. In Study 1, the essentialist explanation required participants to agree that all members in the pictured group had the same kinds of things inside, which made them all the same kind of thing, which in turn caused them to stay together. In this study, we simplified the essentialist explanation to make it less cognitively taxing for the youngest children. Finally, with this study we investigated whether results from children would replicate findings from the first study, and we included adults as a developmental end-point. As we were most interested in comparing the youngest and oldest elementary school ages with adults, we did not include an 8–9-year-old group in this study.

Method

Participants

The participants were 38 children grouped in two non-overlapping age and grade ranges: *6- to 7-year-old group*, $N = 19$ (6 males, 13 females), age range = 6.1 years to 7.1 years (mean age = 6.2 years), grade range = K–1; *10- to 12-year-old group*, $N = 19$ (7 males, 12 females), age range = 10.0 years to 12.9 years (mean age = 10.8 years), grade range = 4–7. Twenty-two adults from the university and the community also participated. The majority of the adult and child participants were Caucasian; one was African-American, four were Hispanic, and one was Asian-American.

Written consent was obtained from all adult participants and from parents of the child participants. Verbal assent was also given by each child. Participants were interviewed in their homes or in the university laboratory with the procedure lasting about 20 minutes. To verify interviewer reliability and to check the accuracy of the transcripts, interviews with the children were audiotaped. Small tokens were given to each child who participated in the study.

Materials and procedure

The same set of naturalistic photographs as used in Study 1 was used in Study 2, with the exclusion of the insect category and the set of practice cards used in Study 1. These cards were excluded to reduce the length of the procedure since two additional questions were added in this study. Thus, we used nine photographs in this study, representing three biological categories (humans, ungulates, plants).

The set of nine cards was presented twice, with all cards being presented in random order, one at a time, for each presentation. The first time the set was presented, participants were asked for each picture: 'Why do all these Xs stay together'. As in Study 1, participants rank ordered the three explanations from the best to the worst, using the same visual mnemonics for each picture. The intentional and teleological explanations were the same as in Study 1: intentional, 'They stay together because they *like* each other'; teleological, 'They stay together because they will be *safe* from danger'. The essentialist explanation differed: 'They stay together because of what they all have *inside*.'

The participants were then presented with the same nine picture cards a second time. In this presentation, participants were asked two questions for each picture: (1) 'Why do these X's breathe?', and (2) 'Why do these X's dream?' The question order was alternated so that the breathe question was asked first for one picture and the dream question was asked first for the next picture, and so on. Again, the participants rank ordered the explanations from best to worst. The explanations were as follows: intentional, 'They breathe/dream because they *like* to breathe/dream', teleological, 'They breathe because their bodies *need* air to stay alive/They dream because they *need* to keep their minds active', essentialist, 'They breathe/dream because of what they all have *inside*'.

Scoring

Scoring was done in the same way as in Study 1. Chance was 1.

Results

Overall analysis

The explanation preference scores for the children were analysed in a 3 (age group: 6–7-year-olds, 10–12-year-olds, adults) $\times$ 3 (explanation: intentional, teleological, essentialist) $\times$ 3 (biological category: human, ungulate, plant) $\times$ 3 (question: stay together, breathe, dream) mixed design ANOVA, with explanation, biological category, and question as repeated measures (see Figs 2, 3 and 4 for means and standard errors). Analyses indicated a significant main effect for explanation, $F(2,114) = 44.51$, $p < .0001$. Additionally, there was a significant explanation $\times$ age group interaction, $F(4,114) = 9.62$, $p < .0001$, a question $\times$ explanation interaction, $F(4,228) = 50.75$, $p < .0001$, and an explanation $\times$ biological category interaction $F(4,228) = 34.73$, $p < .0001$. Finally, there was a question $\times$ explanation $\times$ age group interaction $F(8,228) = 8.72$, $p < .0001$ and a question $\times$ explanation $\times$ biological category interaction, $F(8,456) = 23.75$, $p < .0001$. To clarify the nature of the interactions, and to permit direct comparisons with the results from Study 1, analyses will be presented separately for each question, for the intentional, teleological and essentialist explanations, in turn.

Stay together question

As was found in Study 1, the intentional explanation was preferred for humans, the teleological explanation was preferred for ungulates and the essentialist explanation was preferred for plants. In addition, the 6–7-year-old children preferred the intentional explanation more and the essentialist explanation less, than did the 10–12-year-old children and adults.

The explanation preference scores were analysed in a 3 (age group: young, old, adult) $\times$ 3 (explanation: intentional, teleological, essentialist) $\times$ 3 (biological category: human, ungulate, plant) mixed design ANOVA, with explanation and biological category as repeated measures (see Fig. 2 for means and standard errors). Analyses indicated a significant main effect for explanation, $F(2,114) = 18.74$, $p < .0001$.

Additionally, there was a significant explanation × age group interaction, $F(4,114) = 5.9$, $p < .0002$, and a biological category × explanation interaction, $F(4,228) = 47.21, p < .0001$. More importantly, there was an explanation × biological category × age group interaction, $F(8,228) = 2.01, p < .05$.

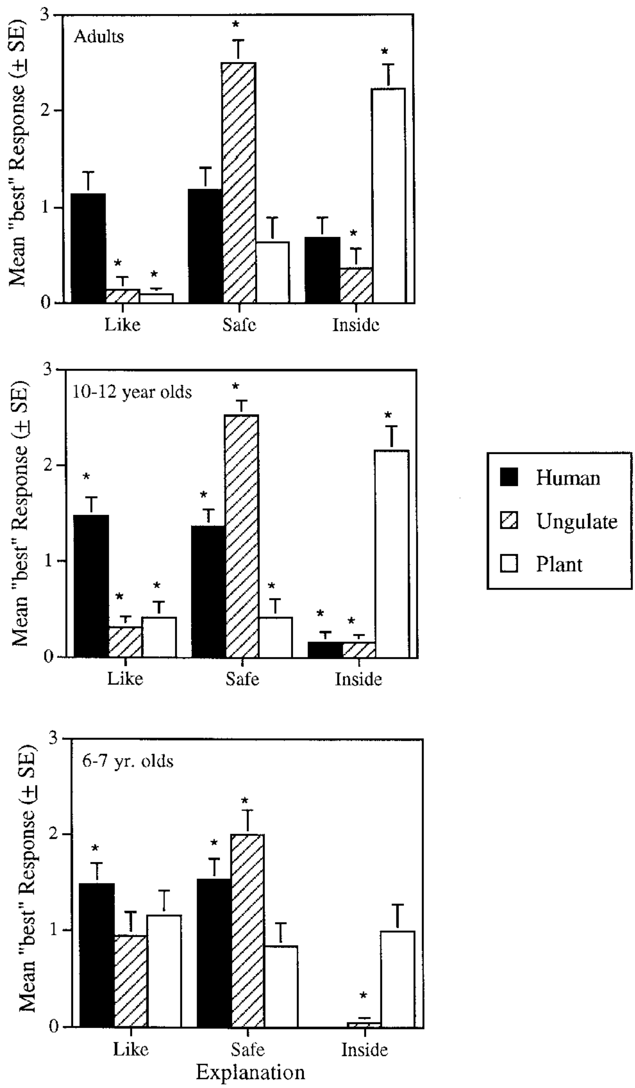

Figure 2. Study 2: Why do they stay together? Patterns of explanation preference across three biological categories for ages, 6 years to adult (*Chance= 1; p<.05)

Intentional explanation (like)

An age group (3) × biological category (3) ANOVA on the scores for the intentional explanation indicated significant main effects for age, $F(2,57) = 11.33, p < .0001$, and for biological category, $F(2,114) = 21.07, p < .0001$. Bonferroni *post hoc* comparisons indicated greater preference for the intentional explanation by the 6–7-year-old children as compared with both the 10–12-year-old children ($p < .01$) and adults ($p < .0001$). In addition, the intentional explanation was preferred more for humans than for any other biological category, by all age groups (all *ps* < .0001).

Teleological explanation (safe)

A similar ANOVA on the scores for the teleological explanation indicated a significant main effect for biological category, $F(2,114) = 48.55$, $p < .0001$. Bonferroni *post hoc* comparisons collapsed across age groups indicated that the teleological explanation was preferred more for the ungulates than for any other category (all *ps* < .0001). In addition, the teleological explanation was preferred more for the humans than for the plants ($p < .0001$)

Essentialist explanation (inside)

A similar ANOVA on the scores for the essentialist explanation indicated significant main effects for age, $F(2,57) = 9.81$, $p < .0002$, and biological category $F(2,114) = 71.93$, $p < .0001$. An age group × biological category interaction was also found, $F(4,114) = 2.95$, $p < .03$. Bonferroni *post hoc* comparisons indicated that the adults preferred the essentialist explanation more for the plants than did the 6–7-year-old group ($p < .002$); as well, the 10–12-year-old children preferred the essentialist explanation more for plants than did the youngest children (*ps* < .004).

As in Study 1, age group (3) × explanation (3) ANOVAs were conducted for the stay together question, for each biological category in turn.

Human category

This analysis for the human category revealed a significant main effect for explanation, $F(2,114) = 20.09$, $p < .0001$. Bonferroni *post hoc* comparisons indicated that the intentional explanation was used more for the humans than was the teleological explanation ($p < .01$) and the teleological explanation was used more for the humans than the essentialist explanation ($p < .01$), collapsed across age groups.

Ungulate category

In a similar analysis, a significant main effect for explanation was found for the ungulate category, $F(2,114) = 81.48$, $p < .0001$, and an explanation × age group interaction was also found $F(2,114) = 2.90$, $p < .05$. Bonferroni *post hoc* comparisons indicated that the teleological explanation was preferred more for the ungulates than the intentional explanation (*ps* < .0001) and the essentialist explanation (*ps* < .0001) for all age groups, though the effect was greatest for the adults.

Plant category

In a similar analysis, a significant main effect for explanation, $F(2,114) = 18.70$, $p < .0001$, and an explanation × age group interaction, $F(4,114) = 5.24$, $p < .005$, were found for the plant category. Bonferroni *post hoc* comparisons indicated that the essentialist explanation was preferred more for the plants than was the intentional explanation (*ps* < .002) and the teleological explanation (*ps* < .006) by the 10–12-year-olds and the adults. The 6–7-year-old children did not show a preference for any of the explanations for the plant category.

Breathe question

Overall, for the breathe question, all three groups showed a strong preference for the teleological explanation (see Fig. 3) for all biological categories. The explanation preference scores were analysed in a 3 (age group: 6–7-year-old, 10–12-year-old, adult) × 3 (explanation: intentional, teleological, essentialist) × 3 (biological category: human, ungulate, plant) mixed design ANOVA, with explanation and biological category as repeated measures (see Fig. 3 for means and standard errors). Analyses indicated a significant main effect for explanation, $F(2,114) = 157.54$, $p < .0001$. Additionally, there was a significant explanation × age group interaction, $F(4,114) = 6.82$, $p < .0001$, and a biological category × explanation interaction, $F(4,228) = 3.83$, $p < .005$.

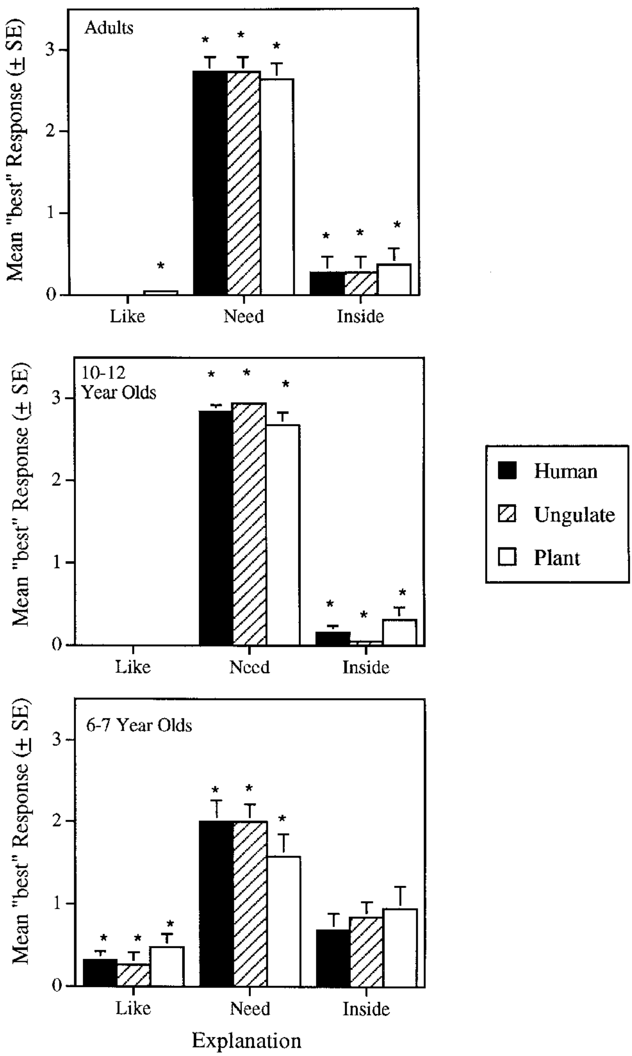

Figure 3. Study 2: Why do they breathe? Patterns of explanation preference across three biological categories for ages, 6 years to adult (*Chance= 1; p<.05)

Intentional explanation (like)

In an age group (3) × biological category (3) ANOVA, a significant main effect for age was found, $F(2,57) = 11.56$, $p < .0001$. Bonferroni *post hoc* comparisons indicated that the 6–7-year-old children preferred the intentional explanation more than did the 10–12-year-old children ($p < .0001$), and adults ($p < .0001$). However, even the 6–7-year-olds chose intention at significantly less than chance levels (see Fig. 3).

Teleological explanation (need)

Significant main effects for age, $F(2,57) = 8.41$, $p < .0006$, and for biological category, $F(2,114) = 6.59$, $p < .002$ were found. Bonferroni *post hoc* comparisons indicated that the 10–12-year-old children and adults used the teleological explanation more than the 6–7-year-old children did (*p*s < .0001). In addition, the teleological explanation was preferred more for the human ($p < .006$) and ungulate ($p < .002$) when compared to plants.

Essentialist explanation (inside)

A significant main effect was found for age, $F(2,57) = 4.30$, $p < .02$, with Bonferroni *post hoc* comparisons indicating that the 6–7-year-old children chose the essentialist explanation more than the 10–12-year-old children ($p < .0001$), or adults ($p < .0006$). However, this finding should be qualified by the fact that the 10–12-year-old children and adults rejected the essentialist explanation, and the 6–7-year-old group's preference score was not significantly different from chance. Thus, none of the age groups demonstrated a preference for essentialism.

Dream question

Overall, for all biological categories, the 6–7-year-old children preferred the intentional explanation, the 10–12-year-old children did not demonstrate any significant explanation preferences and the adults preferred the essentialist explanation.

The explanation preference scores were analysed in a 3 (age group: 6–7-year-old, 10–12-year-old, adult) × 3 (explanation: intentional, teleological, essentialist) × 3 (biological category: human, ungulate, plant) mixed design ANOVA, with explanation and biological category as repeated measures (see Fig. 4 for means and standard errors). Analyses indicated a significant explanation × age group interaction, $F(4,114) = 11.63$, $p < .0001$, which is investigated in the following analyses.

Intentional explanation (like)

In an age group (3) × biological category (3) ANOVA, a significant main effect for age was found, $F(2,57) = 14.31$, $p < .0001$. Bonferroni *post hoc* comparisons indicated a greater preference for the intentional explanation by the 6–7-year-old children when compared with the 10–12-year-old children ($p < .001$) and adults ($p < .0001$). In addition, the 10–12-year-olds preferred intention more than the adults did ($p < .0003$).

Teleological explanation (need)

There were no significant differences by age in the use of the teleological explanation for the dream question.

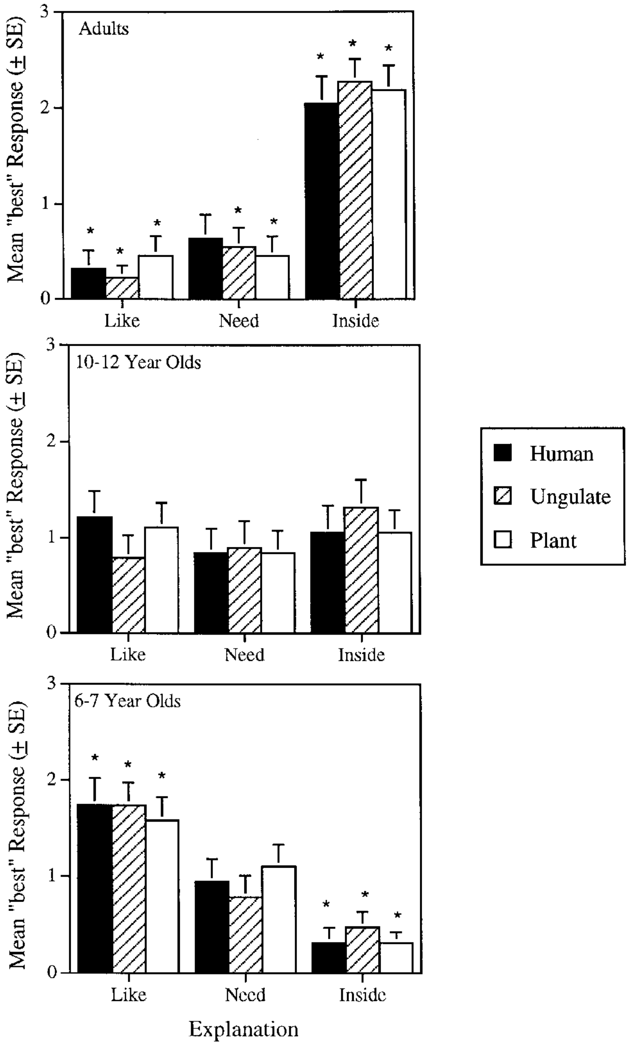

Figure 4. Study 2: Why do they dream? Patterns of explanation preference across three biological categories for ages, 6 years to adult (*Chance= 1; p<.05)

Essentialist explanation (inside)

A significant main effect was found for age, $F(2,57) = 19.50, p < .0001$. Bonferroni *post hoc* comparisons indicated that the adults preferred the essentialist explanation more than the 10–12-year-old children ($p < .0001$) and 6–7-year-old children ($p < .0001$) did. In addition, the 10–12-year-old children preferred the essentialist explanation more than the 6–7-year-olds did ($p < .0001$).

Discussion

In Study 2, children and adults were presented with different contexts in which they could evaluate the behaviours of different biological groups. These contexts included a neutral grouping behaviour (stay together), and two individual behaviours, a biological behaviour (breathe) and a psychological behaviour (dream). Results from this study revealed several differences related to age of participant, type of behaviour and biological category.

Findings from this study replicate and extend those of Study 1. For the stay together question the teleological explanation (safe from danger) was preferred for the ungulates across all age groups. In addition, the intentional explanation was used more by the 6–7-year-olds than the other age groups for all three of the behaviours used in this study (stay together, breathe, dream). Moreover, the essentialist explanation (same inside) was preferred for plants more than for any other biological category by the adults and the 10–12-year-olds. However, as in Study 1, the youngest children used essentialism less than participants in the other age groups; in fact, their use of essentialism did not exceed chance levels.

For the prototypical biological behaviour, breathing, all age groups preferred the teleological explanation for all biological categories, although in comparison with the other age groups, the 6–7-year-old children used teleology less. These results support other findings that by early elementary school, children have a clear understanding of prototypical biological behaviours (see Wellman & Gelman, 1998 for a review).

On the other hand, for the prototypical psychological behaviour, dreaming, there was a significant age-related interaction in the overall pattern of explanation preference with the adults showing a strong preference for the essentialist explanation across all biological categories and the 6–7-year-old children relying on intention. For the 10–12-year-olds every explanation was at chance for all biological categories, indicating that they did not find any explanation preferable. However, 10–12-year-olds were less likely than adults to endorse intention and more likely than 6–7-year-olds to endorse essentialism. This interesting pattern of results suggests that the 10–12-year-olds' preference pattern represents a transition from an earlier preference for intention to a more mature preference for essentialism.

Given the ambiguity of the dream question, especially for the plants, we argue that 6–7-year-olds were using intention as a default, whereas adults used essentialism as a default, finding no other explanation acceptable (Gelman, S. *et al.*, 1994). The transitional age group, the 10–12-year-olds, though, did not appear to have any default explanation easily available. These findings are consistent with the interpretation that there is a qualitative shift in the use of essentialist explanations over the elementary school years and into adulthood. Overall, the results from Study 2 provide further evidence that children and adults do exhibit flexibility in their use of explanations across different biological categories and behaviours.

GENERAL DISCUSSION

A strength of the current studies is the targeting of taxa that differ in degree from the human, which has revealed that even within the world of living things neither adults nor children are wedded to any one mode of explanation (see also Gutheil *et al.*, 1998; Schult & Wellman, 1997). However, adults and older elementary school children

(10–12 years) were much more likely than younger children (6–7 years) to make fine-grained discriminations between biological kinds when applying these explanations. When placed in the broader context of related studies, the current study lends support to the position that reasoning about something as complex as the behaviour of animate entities requires the coordination of multiple cues (Keil & Wilson, 2000; Gelman, R. *et al.*, 1995), and no single explanation is likely to suffice.

The pattern of explanation preferences shown in these studies indicates that both stability and change characterize the development of a naïve biology during the elementary school years. Stable features include the capacity to demonstrate flexibility: adults and elementary school children alike endorse different explanations depending on the behavioural context. However, change is apparent also, as demonstrated by the overall decrease in preference for intentional explanations and the increase in preference for essentialist ones, from the early elementary school years into adulthood. Before considering how these results relate to previous conclusions about the nature of a naïve biology, we examine in more detail the roles of causal flexibility and essentialism in the emergence of an intuitive biology.

Causal flexibility

These results support those of earlier studies and indicate that children approach the world of living things with a multiplicity of explanatory systems each characterized by general causal principles (Gutheil *et al.*, 1998; Keil *et al.*, 1999; Schult & Wellman, 1997). Intentionality seems to be one of the most salient of these systems at early ages (Gutheil *et al.*, 1998). However, this is not to suggest that the teleological or essentialist modes were inconsequential. Adults and the 10–12-year-old children were most likely to favour essentialist explanations for the insects or plants. Yet, teleology emerged as the favoured explanation for ungulates, especially by the 10–12-year-olds and the adults. Even the 6–7-year-olds overwhelmingly preferred teleology for prototypical biological entities and behaviours (see Carey, 1985): the non-human mammals (ungulates in these studies) and breathing. When 6–7-year-olds endorsed intention it was most likely to be for the prototypical psychological entity, the human, or for behaviours for which no other explanation might have seemed appropriate, such as dreaming (see also Flavell *et al.*, 1997; Miller & Bartsch, 1997)

These findings provide more support for the central thesis of this paper that causal flexibility is a hallmark of human reasoning capacities, for both adults and children. This capacity is as necessary, we claim, for the expert as it is for novices, as explanations for phenomena must be modified, transformed, or interconnected (Keil & Wilson, 2000), as new causal mechanisms and concepts come to light.

Reworking essentialism

Why was the essentialist explanation favoured less often by children than by adults in these studies? As described earlier, researchers have demonstrated that some types of essentialist explanations are used by preschool children (aged 3–5 years) to explain the behaviour of individuals (e.g. Gelman, S. *et al.*, 1994; Gelman, R., 1990). However, in our studies it was not until 8 or 9 years of age that children showed a preference for the essentialist explanation, and even then they reserved it mainly for plants. Most studies, though, do not pit essentialism against the other stances. Gelman, S. and Hirschfeld

(1999) have suggested that essentialist explanations are invoked in the absence of compelling alternatives.

Nonetheless, there are several potentially interesting explanations of these findings, all of which imply a possible shift in an understanding of essentialism from the elementary school years to young adulthood. The lack of preference for essentialist reasoning among children in the present studies does not appear to be a result of their failure to understand the importance of 'insides' (see Gelman, S. & Wellman, 1991; Massey & Gelman, 1988), but rather to the way the children conceptualized this insight. The essentialist explanation 'all have the same things inside' could elicit multiple interpretations as it was deliberately content-neutral. Despite the visual mnemonic representing essentialism, some children in the first study initially denied the essentialist explanation with individualizing comments such as, 'They don't all have the same things inside', 'they eat different things', 'some are boys and some are girls'. A change in the way the essentialist explanation was worded did not produce any appreciable difference in the results in Study 2. Adults, in contrast, appeared to map the essentialist explanation onto a genetic or quasi-genetic mechanism.

Carey (1996) proposed that 'essentialism, like taxonomic structure, derives from the logical work nouns do' (p. 193) and argued that initially essentialism is driven by the default assumption that the identity of every entity picked out by a given noun is unchanged in the face of surface changes. One possibility, therefore, is that the shift in school-age children's understanding of essentialism may be characterized as a movement from a linguistic essentialism at the level of individual members of a category, to a biological essentialism at the level of the group or species. Our findings suggest that young children have very little sense of a species essence, which, at least for the working naturalist, is the basic biological unit (Mayr, 1982).

An alternative proposal, though, is that 6–7-year-old children may not believe that the 'grouping behaviour' of a living kind has any relationship to its internal structure. Nevertheless, as adults did acknowledge this relationship (as did older children, in the case of plants), the implication is that younger children's interpretation of a species' essence is different from that of adults. That which is granted 'essential' causal power for the expert or lay adult (probably genetic inheritance or an internal biological process), may differ qualitatively in its consequences from the relatively inchoate innards principle attributed to 6–7-year-old children. Moreover, it seems likely that the naturalist's concept of a species essence, which refers to a visible morpho-behavioural breeding unit (Mayr, 1982), as opposed to a category essence, may be motivated by a different understanding of essentialism (Evans, 2001). More detailed investigations of preschool and school-age children's and adults' beliefs about category and species essence are needed to disentangle this issue.

Implications for the nature of a naïve biology

Overall, these results provide evidence for a shift from a preference for teleo-intentional causes to a preference for teleo-essentialist causes for the behaviours of diverse living kinds, from the early school-age years into adulthood. These data support and extend previous proposals that 6–7-year-old school-age children reason about the world of living things from an intentional (Carey, 1985, 1996) or teleological stance (Hatano & Inagaki, 1994; Keil, 1994), while older school-age children and adults reason more mechanistically (Carey, 1999; Inagaki & Hatano, 1993; Keil *et al.*, 1999). In particular, however, we believe these changes represent shifts in 'default biases' (Gutheil *at al.*, 1998). These findings suggest, moreover, that over the elementary school years and into early adulthood the teleological and intentional explanations of young children's intuitive theories become increasingly differentiated, with a gradual incorporation of a biological essentialism.

These findings raise questions about the nature of a folk or naïve biology. Carey (1985, 1999) considered one of the characteristics of an autonomous biology to be the grouping of different species, from humans to plants, under the rubric of a living kind. Clearly in some cases, humans, other animals and plants, were treated identically as living kinds with a need to breathe, by the youngest children in our study, 6–7-year-olds, and the adults. Yet, in different contexts adults and children differentiated between species and behaviours, with 6–7-year-old children more likely to favour intentional explanations and adults more likely to favour essentialist explanations, though, importantly, both endorsed teleological explanations. Is an autonomous biology achieved when individuals demonstrate an understanding that prototypical biological behaviours, such as breathing, do not appear to be subject to intentional control and serve a similar function for all living kinds? If that is the case, then a majority of 6–7-year-old elementary children can reasonably be labelled as biological thinkers. On the other hand, this label may only be justified for individuals who reason flexibly about a range of different behaviours and species, applying non-intentional functional and (internal) mechanistic biological causes only where appropriate. In that case, it is probably only those with biological expertise that qualify.

Several investigators have expressed scepticism about the scope of the biological knowledge of the average lay adult in modern industrial societies, such as the USA or Japan. Evans (2000, 2001); and Hatano and Inagaki (1999) provide evidence that adults, like children, often default to a form of psychological reasoning when explaining biological phenomena. Atran (1999) demonstrates that the biological reasoning of members of the Itzaj Maya forest culture is in many respects superior to that of university-educated US students, while being comparable to that of US parks maintenance workers. Young elementary school children's naïve biology, we contend, may not differ appreciably from that of the ordinary non-expert adult.

In conclusion, we maintain that neither school-age children nor lay adults demonstrate a sophisticated understanding of the biological world, yet in both cases they access broader explanatory principles involving intention, function and internal mechanisms that become more specific and concrete as they learn more about nature (see also Gutheil *et al.*, 1998). Such knowledge is typically acquired (imperfectly) in biology classes for those inhabitants of modern industrialized societies who have become divorced from the natural environment. For inhabitants of indigenous communities this knowledge is embedded in their understanding of the local ecology (Atran, 1999; Ross, Medin, Coley, & Atran, 2001).

We believe that the these results support a position endorsed by Keil and his colleagues (1994; Keil *et al.*, 1999; Keil & Wilson, 2000) that foundational domains (Wellman & Gelman, 1998) are initially characterized by a distinctive mix of abstract intuitive causal principles, such as the intentional, teleological and essentialist stances, not by concrete mechanisms. Nevertheless, these causal intuitions might well enable children (and scientists) to 'guess right' (Keil & Wilson, 2000) most of the time when they are trying to figure out how or why something happens, in the absence of specific knowledge of the phenomenon in question.

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Appendix: Visual mnemonics for intentional (like), teleological (safe/need), and essentialist (inside) explanations