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Brief article

The Human Function Compunction: Teleological explanation in adults

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ABSTRACT

Research has found that children possess a broad bias in favor of teleological – or purpose-based – explanations of natural phenomena. The current two experiments explored whether adults implicitly possess a similar bias. In Study 1, undergraduates judged a series of statements as "good" (i.e., correct) or "bad" (i.e., incorrect) explanations for why different phenomena occur. Judgments occurred in one of three conditions: fast speeded, moderately speeded, or unspeeded. Participants in speeded conditions judged significantly more scientifically unwarranted teleological explanations as correct (e.g., "the sun radiates heat because warmth nurtures life"), but were not more error-prone on control items (e.g., unwarranted physical explanations such as "hills form because floodwater freezes"). Study 2 extended these findings by examining the relationship between different aspects of adults' "promiscuous teleology" and other variables such as scientific knowledge, religious beliefs, and inhibitory control. Implications of these findings for scientific literacy are discussed.

1. Introduction

As debates about teaching Intelligent Design in American Schools illustrate, there exists substantial popular resistance to scientific ideas. While many factors contribute to such resistance, part of the explanation may be found in various conceptual biases (e.g., Bloom & Skolnick Weisberg, 2007; Evans, 2000; Gelman, 2003; Kelemen, 1999a; Rosset, 2008; Shtulman, 2006). Among these is an early emerging "promiscuous" teleological tendency to explain all kinds of natural phenomena by reference to a purpose. For example, from preschool, children attribute functions to entities like lions, mountains, and icebergs, viewing them as "made for something" (Kelemen, 1999a). When asked about properties of natural entities like pointy rocks, children prefer teleological explanations over physical–causal ones, endorsing that rocks are pointy "so that animals won't sit on them", not because "bits of stuff piled up over time" (Kelemen, 1999b; but Keil, 1995). Among school-aged children, such teleological intuitions explicitly link to beliefs about intentional causality in nature (Kelemen & DiYanni, 2005) with children's ideas not straightforwardly explained by parental explanations (Kelemen, Callanan, Casler, & Pérez-Granados, 2005) or ambient cultural religiosity (Kelemen, 2003).

Adults, of course, do not show much overt sign of sharing children's beliefs about the intrinsic functionality of icebergs or a rock's sharp edges. Presumably then, children readily outgrow such fanciful purpose-based ideas, especially as their familiarity with ultimate causal explanations increases. Indeed, research with college-educated adults seems to support this trajectory. When tested on child-appropriate tasks, they eschew children's broad teleological endorsements, restricting functional ascriptions to body parts and artifacts (Kelemen, 1999a; Kelemen, 1999b; Kelemen, 2003).

Despite this, however, recent findings hint that "promiscuous teleology" may not be a passing stage of immaturity. For instance, research using child-assessment materials that compared Alzheimer's patients to healthy controls found that teleological intuitions reassert themselves when the coherence of causal knowledge is eroded

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by disease (Lombrozo, Kelemen, & Zaitchik, 2007). This raises the possibility that rather than being part of a childhood stage, teleological explanation remains an explanatory default throughout development. That is, while the acquisition of scientifically warranted causal explanations might suppress teleological ideas, it does not replace them. This "co-existence" position makes a prediction: Even healthy, schooled adults should display scientifically unwarranted promiscuous teleological intuitions when their capacity to inhibit more primary purpose-based intuitions is impaired by processing demands. To test this, we asked undergraduates to judge the correctness of warranted and unwarranted explanations of various natural phenomena under speeded conditions.

2. Study 1

2.1. Method

2.1.1. Participants

Participants were 121 university students, randomly divided into one of three conditions: fast speeded ($n = 42$), moderately speeded ($n = 40$), and unspeeded ($n = 39$). Science class background did not differ across groups. Participants averaged 2.5 (SD = 2) completed college science classes.

2.1.2. Procedure

In a classroom setting, groups of 5–10 participants read through the instructions with an experimenter. For the two experimental (i.e., speeded) conditions, these indicated that participants would see explanations for "why things happen" appear one at a time on an overhead screen, and that they were to decide whether the sentence described a correct ("good") or incorrect ("bad") explanation by checking the appropriate box on an answer sheet. The experimenter explicitly stated in her instructions that "by *good* we mean *correct*" and offered non-teleological examples of both "good" and "bad" explanations so that the "correct" versus "incorrect" contrast was clear. The conversational terms "good" and "bad" were selected as response options rather than "correct" and "incorrect" because of methodological issues associated with asking for speeded judgments that require negation of the alternative response option. Control (i.e., unspeeded) participants followed the same procedure but read the sentences directly on the answer sheets.

2.1.3. Stimuli

Stimuli were 80 sentences describing simple explanations for why things happen: 26 test sentences and 54 control sentences. The test sentences described scientifically unwarranted purpose-based explanations for biological (e.g., "ferns grow in forests because they provide ground shade"; $n = 10$) and non-biological (e.g., "the sun radiates heat because warmth nurtures life"; $n = 16$) natural phenomena. Table 1 provides samples.

Four types of control sentences were designed to track participants' abilities to evaluate sentences at speed. Two types were "good" explanations that were either teleological ($n = 8$; e.g., "stoplights change color because they control traffic") or causal ($n = 24$; e.g., "water freezes because the temperature drops"). Two types involved unwarranted, incongruous "bad" explanations that were either teleological ($n = 6$; e.g., "animals grow ears because they need to smell things") or causal ($n = 16$; e.g., "polar bears are white because the sun bleaches them"). Test items included, there were equal numbers of teleological versus causal explanations and explanations meriting "good" versus "bad" judgments.

Speeded sentences were presented consecutively in one of two orders, using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Each sentence remained on screen for either 3200 ms (fast speeded condition) or 5000 ms (moderately speeded condition) after which the next sentence appeared automatically. A pause, indicated by an "*" and ended by the experimenter's keypress, was inserted every 10 sentences to prevent people from losing their place due to a missed item and to give time to turn the page. The stimuli were divided into 10 blocks of 10 sentences each. Each block contained seven control sentences (two teleological, five causal) and three teleological test sentences. Two blocks of practice items were excluded from analyses.

Table 1
Sample items included in both Study 1 and 2 (presented with Study 2 phrasing and using Study 2 item type labels).

Explanation type	Test items
Implicit biological	Earthworms tunnel underground to aerate the soil Mites live on skin to consume dead skin cells Mosses form around rocks to stop soil erosion
Explicit biological	Finches diversified in order to survive Germs mutate to become drug resistant Parasites multiply to infect the host*
Implicit non-biological	The sun makes light so that plants can photosynthesize Water condenses to moisten the air Molecules fuse in order to create matter
Explicit non-biological	Earthquakes happen because tectonic plates must realign Geysers blow in order to discharge underground heat The earth has an ozone layer to protect it from UV light*
Explanation type	Control items
Good physical	Flowers wilt because they get dehydrated Bread rises because it contains yeast People get the flu because they catch a virus
Bad physical	Zebras have black stripes because they eat coal Gusts of wind occur because animals exhale together Clouds form because bits of cotton collect together
Good teleological	Children wear gloves to keep their hands warm Teapots whistle to signal the water is boiling People buy vacuums because they suck up dirt
Bad teleological	Cars have horns to illuminate dark roads Eyelashes developed so that people can wear mascara Mothers kiss babies in order to scare them

* Item appeared in Study 2 only.

2.2. Results

Each participant's score for control and experimental items was expressed as a proportion of all items answered. In both studies reported here, participants were discarded for failure to answer 25% of the experimental items or get 25% of the control items correct (Study 1, $n = 6$; Study 2, $n = 4$).

Scores on the control items indicated that participants in all conditions could read the sentences in the allotted time, and understood the task. Overall, participants got over 90% of control items correct. Nevertheless one-way ANOVA revealed that the opportunity to "second guess" meant unspeeded participants were statistically less accurate than those in speeded conditions (fast: 94%; moderate: 93%; unspeeded: 91%), $F(2,118) = 4.5$, $p < 0.01$.

Of most interest, however, were the results on the test items. One-way ANOVA on adults' tendencies to endorse unwarranted teleological explanations found that acceptance increased with speed, $F(2,118) = 7.86$, $p < 0.001$. As Table 2 shows, fast speeded participants endorsed, on average, nearly half of the unwarranted teleological explanations (47%), significantly more than in either the moderate (36%) or unspeeded (29%) conditions. Post-hocs revealed that in every condition unwarranted teleological explanations of biological phenomena were endorsed more than those for non-biological natural phenomena although this difference was more marginal in the fast speeded condition, $t(41) = 2$, $p < 0.06$, other $ps < 0.001$.

2.3. Discussion

When processing is limited by speeded conditions, adults are more likely to endorse scientifically unwarranted teleological explanations of natural phenomena. Speeded responding did not reduce the high accuracy of answers to control items, thus participants' endorsement of the unwarranted teleological test items was not due to response biases or limited reading abilities. These findings are therefore consistent with the view that schooled adults preserve a tendency to see purpose in nature.

Study 2 pursued various questions raised by Study 1. First, item analyses indicated that several unwarranted teleological explanations were equivalently well-accepted at all speeds. It was possible that these items tapped teleological beliefs so explicitly held that they are never inhibited. Indeed, these items shared a similarity: While the other explanations involved other-serving functions, such as the sun making light for plants, these items had more self-preserving goals, either for the organism itself, or the earth construed as a "Gaia-like" vital organism (Lovelock, 1990) (see Table 1). Study 2 therefore further explored whether adults explicitly construe nature as possessing immanent agency by increasing the number of Earth/self-preserving "Explicit Belief" items.

Table 2
Mean percentage of unwarranted teleological test explanations accepted and control items answered correctly in Study 1.

	Teleo test (bio)	Teleo test (non-bio)	Teleo test total	Physical control correct	Teleo control correct	Control correct total
Fast	51 (24)	44 (20)	47 (18)	92 (6)	96 (5)	94 (4)
Moderate	41 (23)	33 (25)	36 (23)	92 (6)	94 (6)	93 (5)
Unspeeded	35 (26)	26 (14)	29 (17)	90 (7)	91 (8)	91 (6)
Total	43 (25)	35 (21)	38 (21)	91 (6)	91 (8)	93 (5)

Additionally, in Study 2, we modified the wording. To maintain consistency, Study 1 employed "because" as the conjunction for all explanations. Teleological explanations, however, often involve "so that" or "to" phrasing. Although participants' highly accurate responding to teleological controls rendered it unlikely, we wanted to ensure that in Study 1 we had not triggered false positives to test items by obscuring their distinctive teleological status. In Study 2, we therefore varied conjunctions in teleological explanations to include "so that" and "to".

Finally, the co-existence position predicts that schooled adults will endorse unwarranted teleological explanations when they experience inhibitory failures and that these failures will occur most frequently when inhibitory control is poor and when causal knowledge is less robust. Study 2 therefore included individual difference measures of inhibitory control (Stroop task), and knowledge of natural selection and basic geoscience. Personal beliefs in God and natural selection were also assessed.

3. Study 2

3.1. Method

3.1.1. Participants

Participants were 109 university students, randomly assigned to three conditions: fast speeded ($n = 35$), moderately speeded ($n = 40$), and unspeeded ($n = 34$). All participants averaged 2.7 (SD = 2.6) college science courses with no difference between conditions.

3.1.2. Stimuli

The 70 stimuli were largely the same as Study 1, with two modifications. First, instead of 26 teleological test items, Study 2 had 22 teleological items (11 biological and 11 non-biological natural), of which eight were Explicit Belief items containing Earth/self-preservation content. We expected no effect of condition for these items because we predicted that even unspeeded control participants would strongly endorse them (e.g., "the earth has an ozone layer to protect it from UV light"). The remaining 14 Implicit Belief items described unwarranted teleological explanations involving other-serving functions where differences were expected between conditions (e.g., "trees produce oxygen so animals can breathe"). Second, conjunctions in the teleological test items were varied and some minor modifications were made to the wording of some items. The control items were largely taken from Study 1. Including test items, there were 16 correct and 28 incorrect teleological items; 20 correct and 16 incorrect causal items (see Table 1).

3.1.3. Procedure

After completing the explanation judgment task, which was procedurally identical to Study 1, participants com-

pleted a series of multiple choice questions. This included eight questions on Galapagos finch diversity from the Conceptual Inventory of Natural Selection (CINS; Anderson, Fisher, & Norman, 2002); 22 questions from the Geoscience Concept Inventory (GCI; Libarkin & Anderson, 2005; Libarkin & Anderson, 2006); and four ratings of statements concerning personal belief in God, souls, and natural selection (1–5 scale with 5 indicating strong agreement) (see Shtulman, 2006). Personal beliefs in "God" and "souls" were of particular interest because we wanted to explore the relationship between teleological ideas and intuitions about disembodied (intrinsic and extrinsic) intentional agency. Participants were also asked to individually complete a computer-based color naming Stroop task. Scores were calculated by subtracting reaction times to congruent items from reaction times to incongruent ones to create difference scores. Higher Stroop difference scores indicated lower levels of inhibitory control.

3.2. Results

3.2.1. Explanation judgment task

One-way ANOVA revealed that performance on control items did not differ across conditions, $F(2,106) = 2.41$, $p = 0.1$. All participants displayed a high level of accuracy by judging over 93% (SD = 5%) of the items accurately.

As predicted, consistent with Study 1, fast speeded participants were significantly more likely to endorse Implicit Belief items than moderately or unspeeded participants, $F(2,106) = 3.29$, $p < 0.05$ (see Table 3). Furthermore, there was no difference across conditions in adults' tendency to endorse the unwarranted Explicit Belief items, $F(2,106) = 0.40$, $p > 0.6$. Post-hocs revealed that the Explicit Belief items were accepted more than the Implicit Belief items, $t(108) = 11.52$, $p < 0.001$. In contrast to Study 1, however, across both teleological test item types, explanations of non-biological natural phenomena were accepted significantly more than those of living things, $ts(108) = 4.62, 2.04$, respectively, $ps < 0.05$.

3.2.2. Relationship to inhibitory control and scientific knowledge

Preliminary analyses indicated that responses to the Stroop (mean difference = 262 ms, SD = 407), CINS (M = 60% correct, SD = 20%), GCI (M = 41% correct, SD = 15%), and personal belief questions did not differ by condition, all $ps > 0.1$ (see Table 4).

Linear regression with the Stroop, CINS and GCI variables as independent variables (controlling for effects of speed) found that, as predicted, poorer inhibitory control, $b = 0.19$, $t(104) = 2.14$, $p < 0.05$, poorer geoscience knowledge, $b = -0.19$, $t(104) = 2.09$, $p < 0.05$, and poorer natural selection knowledge, $b = -0.32$, $t(104) = 3.47$, $p < 0.05$, significantly predicted individuals' tendencies to endorse Implicit Belief items, $R^2 = 0.23$, $F(4,104) = 7.5$, $p < 0.001$. Correlation analyses confirmed that the contribution of inhibitory control was independent of the contribution by science knowledge in these effects: Stroop scores did not correlate with either CINS or GCI scores although the latter two scores did correlate with each other (speed-partialled $R^2 = -0.36$, $p < 0.001$). Natural selection knowledge (CINS) also negatively correlated with endorsements of Explicit Belief items (speed-partialled $R^2 = -0.20$, $p < 0.05$), however the regression was not significant.

3.2.3. Relationship to personal beliefs

Research has found that elementary school children's teleological intuitions about nature correlate with their view of natural phenomena as caused by God (Kelemen & DiYanni, 2005). In Study 2, speed-partialled correlations revealed that while adults' endorsements of both Implicit and Explicit Belief items negatively correlated with beliefs in natural selection and marginally positively correlated with belief in souls, they did not correlate with ratings of belief in God (Table 4). Regressions on both teleological test item types using speed and entering all four belief ratings as independent variables were also not significant.

3.3. Discussion

Consistent with Study 1, Study 2 indicates that, even after completing multiple college level science courses, adults possess scientifically unwarranted teleological explanations of natural phenomena. Furthermore, while some of these unwarranted purpose-based ideas are brought into sharpest relief when processing demands are limited and capacities to inhibit them with scientific knowledge more fragile, others are overt beliefs that are readily displayed regardless of processing limitations. Specifically, in addition to tacitly harboring beliefs that natural phenomena exist to benefit each other (e.g., "bees frequent flowers to aid pollination"), college-educated adults explicitly construe such phenomena as intrinsically directed towards survival (e.g., "finches diversified in order to survive") and maintaining the Earth's natural equilibrium (e.g., "fungi grow in forests to help decomposition"). Perhaps most striking is how strongly such scientifically unwarranted beliefs are held. Across conditions, Explicit Belief items were endorsed over 70% of the time.

It should also be noted that in Study 2 acceptance was particularly marked for items concerning non-biological natural phenomena (e.g., "lightning occurs to release

Table 3
Mean percentage of unwarranted Explicit and Implicit Belief test teleological explanations accepted in Study 2.

	Explicit (bio)	Explicit (non-bio)	Explicit total	Implicit (bio)	Implicit (non-bio)	Implicit total	Test total
Fast	73 (28)	77 (25)	74 (23)	49 (25)	60 (20)	54 (19)	61 (15)
Moderate	63 (28)	83 (23)	73 (21)	44 (25)	46 (25)	45 (22)	55 (20)
Unspeeded	61 (33)	79 (24)	70 (22)	40 (24)	43 (26)	42 (23)	52 (20)
Total	66 (30)	80 (24)	72 (22)	45 (25)	49 (25)	47 (22)	56 (19)

Table 4
Mean ratings of personal beliefs on 1–5 scale (5 = high agreement) and correlations with test teleological explanations.

	I believe in existence of God	I believe in existence of souls	Natural selection explains human origins	Natural selection explains origin of non-human species
Means	3.6 (1.6)	3.8 (1.3)	3.7 (1.3)	3.7 (1.3)
Correlation co-efficients (R^2) with beliefs				
Implicit Belief Test	0.10	0.17[b]	−0.19[a]	−0.20[a]
Explicit Belief Test	0.02	0.17[b]	−0.05	−0.09
God	–	0.73[a]	−0.40[a]	−0.22[a]
Souls		–	−0.35[a]	−0.17[a]
Natural selection (Humans)				0.60[a]

[a] $p < 0.05$, two-tailed.
[b] $p < 0.05$, one-tailed.

electricity"). From a theoretical standpoint, this is at odds with proposals that throughout development, teleological ideas are intuitively restricted to explain properties of biological entities such as body parts (Atran, 1995; Greif, Kemler Nelson, Keil, & Gutierrez, 2006; Keil, 1992). From an applied standpoint, it represents a warning for science education. Teleological beliefs have long been recognized as an impediment to life sciences instruction (e.g., Brumby, 1985). What the present findings reveal is that they are an issue for the physical sciences as well.

4. General discussion

When examined using child-appropriate materials, children's and adults' teleological intuitions differ in scope (Kelemen, 1999a; Kelemen, 1999b; Kelemen, 2003; Lombrozo et al., 2007; but see Casler & Kelemen, 2008). The present findings indicate, however, that when tested using subtler measures, adults – particularly those with poorer inhibitory control – reveal a tendency to broadly explain living and non-living natural phenomena by reference to a purpose. These results are consistent with the proposal that teleological explanation is maintained as an explanatory default throughout development – one suppressed rather than replaced by the acquisition of scientifically warranted explanations.

These findings also reveal that despite exposure to the causal explanations characterizing contemporary science, adults maintain certain scientifically unwarranted teleological ideas very explicitly. As already suggested, one possibility regarding such explicit beliefs is that they are all manifestations of a coherent underlying Gaia-type theory of "Earth/Nature" as a vital or intentional organism – an agent comprised of biological and non-biological sub-systems that self-regulate and maintain overall equilibrium through a combination of their own volition or Nature/Earth's benevolent control. Certainly, our creation of additional Study 2 "Explicit Belief" stimuli was aided by "channeling" intuitions like these which, importantly, might also underpin more implicit other-serving beliefs: Notions that entities exist for other aspects of the natural system (e.g., "the sun radiates heat because warmth nurtures life") are consistent with a view of Nature as a goal-directed, self-preserving organism.

An alternative possibility, however is that no such coherent underlying theory exists and explicit teleological ideas such as "germs mutate to become drug resistant" or "earthquakes happen because tectonic plates must realign" are isolated false beliefs, acquired independently in a piecemeal fashion. If there is any underlying connection, it might be, at most, that such explanations tap a general, cognitively primitive, presumption that if a phenomenon performs a compelling or salient functional consequence, that activity probably "caused" it. This latter possibility raises a number of questions. For example, what features must a particular functional activity have in order to be judged so compelling as to be explanatory of the phenomenon that produces it? A close fit between function and physical structure might offer one answer and yet this cannot be a general solution: For instance, there is nothing intrinsic to an earthquake's structure that clearly renders it for realigning tectonic plates (despite adult notions to the contrary). This issue aside, proposals concerning a primitive teleological construal certainly have theoretical precedent (Keil, 1992; Keil, 1995; Lombrozo & Carey, 2006; Wright, 1973) and some empirical support (Lombrozo et al., 2007).

Finally, a further alternative account of results might argue that questions concerning the theoretical coherence underpinning any teleological bias are more secondary than questions of computational complexity. Perhaps, adults are more prone to make errors on teleological items at speed because evaluation of teleological explanations is a two-step process: Before judging a teleological item, perhaps participants first have to recover the causal explanation underlying it because teleological explanations apparently state a phenomenon's effect as its' cause in reverse causal fashion.

Several facets of our data – aside from the fact that unspeeded participants accepted many of our teleological explanations – render this an unlikely account of our speeded results. First, this computational view predicts that, in addition to test sentences, participants should, in general, become more prone to incorrectly evaluate teleological control sentences than physical control sentences as speed increases. Anovas comparing "bad" teleological versus "bad" physical controls and "good" teleological versus "good" physical controls across the speeded conditions of Study 1 and Study 2 found no evidence of this. No effects of speed were found and accuracy on teleological and physical controls was either equivalent or occasionally gave teleological control responses an edge. Second, the important Study 2 finding that individuals with poorer inhibitory control were more susceptible to unwarranted teleological explanation is entirely consistent with our co-existence account but the computational account does not predict it. It should be noted that the inhibitory control finding (along with the high accuracy of performance on control items) is also inconsistent with suggestions that

teleological explanations were generally misread as statements about a phenomenon's effect (e.g. "earthworms tunnel underground AND aerate the soil") rather than explanations of that phenomenon.

In summary, it remains for future research to clarify what factors and beliefs promote and underlie college-educated adults' promiscuous teleological ideas, as well as the relationship between children's and adults' teleological beliefs. Specifically, prior research has revealed that elementary school children's teleological beliefs about nature are linked to explicit notions about an extrinsic intentional designer (Kelemen & DiYanni, 2005). By contrast, no link between belief in God and unwarranted teleological ideas was found in the present research (see also Lombrozo et al., 2007). Is this evidence of a developmental discontinuity, suggesting perhaps that children's and adults' promiscuous teleological tendencies are, at some level, dissimilar phenomena? Such a conclusion might prove premature if future findings confirm that intuitions about agency – albeit a Gaia-like agency that is intrinsic rather than extrinsic to nature – underpins adults' teleological ideas. In the present data, correlations between teleological ideas and personal belief in souls are perhaps suggestive. Regardless, the bottom line implied by the current findings remains that, like children, college-educated adults display scientifically unwarranted teleological explanations with ease. Such findings highlight the challenges faced by educators in both the life and physical sciences. The source of popular resistance to scientific ideas appears to run deep.

References

Anderson, D. L., Fisher, K. M., & Norman, G. J. (2002). Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching, 39*, 952–978.

Atran, S. (1995). Causal constraints on categories. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition: A multi-disciplinary debate* (pp. 263–265). Oxford: Clarendon Press.

Bloom, P., & Skolnick Weisberg, D. (2007). Childhood origins of adult resistance to science. *Science, 316*, 996–997.

Brumby, M. (1985). Misconceptions about the concept of natural selection by medical biology students. *Science Education, 68*, 493–503.

Casler, K., & Kelemen, D. (2008). Developmental continuity in teleo-functional explanation: Reasoning about nature among Romanian Romani adults. *Journal of Cognition and Development, 9*, 340–362.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphical system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Research Methods, Instruments, and Computers, 25*, 257–271.

Evans, E. M. (2000). The emergence of beliefs about the origin of species in school-age children. *Merrill Palmer Quarterly, 46*, 221–254.

Gelman, S. A. (2003). *The essential child: Origins of essentialism in everyday thought*. New York: Oxford University Press.

Greif, M. L., Kemler Nelson, D. G., Keil, F. C., & Gutierrez, F. (2006). What do children want to know about animals and artifacts? Domain-specific requests for information. *Psychological Science, 17*, 455–459.

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

Keil, F. C. (1995). The growth of causal understandings of natural kinds. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition: A multi-disciplinary debate* (pp. 234–262). Oxford: Clarendon Press.

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

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

Kelemen, D. (2003). British and American children's preferences for teleo-functional explanations of the natural world. *Cognition, 88*, 201–221.

Kelemen, D., Callanan, M., Casler, K., & Pérez-Granados, D. R. (2005). Why things happen: Teleological explanation in parent-child conversations. *Developmental Psychology, 41*, 251–264.

Kelemen, D., & DiYanni, C. (2005). Intuitions about origins: Purpose and intelligent design in children's reasoning about nature. *Journal of Cognition and Development, 6*, 3–31.

Libarkin, J. C., & Anderson, S. W. (2005). Assessment of learning in entry-level geoscience courses: Results from the geoscience concept inventory. *Journal of Geoscience Education, 53*, 394–401.

Libarkin, J. C., & Anderson, S. W. (2006). The Geoscience Concept Inventory: Application of Rasch analysis to concept inventory development in higher education. In X. Liu (Ed.), *Rasch applications in science education*. Washington, D.C: JAM Publishing.

Lombrozo, T., & Carey, S. (2006). Functional explanation and the function of explanation. *Cognition, 99*, 167–204.

Lombrozo, T., Kelemen, D., & Zaitchik, D. (2007). Inferring design: Evidence of a preference for teleological explanations in patients with Alzheimer's disease. *Psychological Science, 18*, 999–1006.

Lovelock, J. E. (1990). Hands up for the Gaia hypothesis. *Nature, 344*, 100–102.

Rosset, E. (2008). "It's no accident": Our bias for intentional explanations. *Cognition, 108*, 771–780.

Shtulman, A. (2006). Qualitative differences between naïve and scientific theories of evolution. *Cognitive Psychology, 52*, 170–194.

Wright, L. (1973). *Functions. Philosophical Review, 82*, 139–168.