Anthropocentric by Default? Attribution of Familiar and Novel Properties to Living Things

Melanie Arenson, a John D. Coley b

aDepartment of Medicine, University of California, San Francisco & San Francisco VA Medical Center
bDepartment of Psychology, Northeastern University

Received 13 December 2016; received in revised form 14 March 2017; accepted 15 March 2017

Abstract

Humans naturally and effortlessly use a set of cognitive tools to reason about biological entities and phenomena. Two such tools, essentialist thinking and teleological thinking, appear to be early developmental cognitive defaults, used extensively in childhood and under limited circumstances in adulthood, but prone to reemerge under time pressure or cognitive load. We examine the nature of another such tool: anthropocentric thinking. In four experiments, we examined patterns of property attribution to a wide range of living and non-living objects, manipulating time pressure, response type, and property (either novel or familiar) in a total of 471 participants. Results showed no tendency toward increased similarity-based attribution patterns indicative of anthropocentric thinking under time pressure. However, anthropocentric thinking was consistently observed for unfamiliar properties. These findings suggest that anthropocentric thinking is not a developmentally persistent cognitive default, but rather a cognitive strategy deliberately employed in situations of uncertainty.

Keywords: Anthropocentric thinking; Intuitive biology; Property projection; Concepts; Reasoning; Science education

1. Introduction

Across a variety of different knowledge domains and contexts, humans regularly use a set of cognitive tools to reason about different entities and phenomena with which they are confronted. In one such domain—intuitive biology—humans naturally, intuitively, and effortlessly reason about biological entities, structures, processes, and phenomena in predictable ways (Atran & Medin, 2008; Berlin, 1992; Brown, 1984; Carey, 1985; Coley, Solomon, & Shafto, 2002; Inagaki & Hatano, 2006; Medin & Atran, 2004). Coley and
Tanner (2012, 2015) have referred to these ways of thinking as “cognitive construals.” A cognitive construal is an intuitive, often implicit, way of thinking about the world. It might be a set of assumptions, a type of explanation, or a predisposition to a particular type of reasoning. Three such cognitive construals—teleological thinking, essentialist thinking, and anthropocentric thinking—recur in research on the development of intuitive biological thought. Teleological thinking is the tendency to explain an event based on a goal, function, or outcome (e.g., cheetahs evolved to run fast in order to catch their prey). Essentialist thinking is the assumption that members of a category share underlying properties that cause surface regularities, resulting in beliefs that categories are objective and homogeneous (Gelman, 2003; Medin & Ortony, 1989). Anthropocentric thinking is the tendency to use what we know about humans to understand other living things (Carey, 1985; Inagaki & Sugiyama, 1988).

These construals are present early in childhood, and persist into adulthood. They represent powerful, useful, and adaptive principles for organizing what we know about the biological world and allow us to make predictions about what we do not know. However, they may interact with scientific reasoning in unanticipated ways, and as such, may have specific and important implications for teaching and learning formal biological science (Coley, Arenson, Xu, & Tanner, 2017; Coley & Tanner, 2012, 2015; Evans, 2013; Gelman & Rhodes, 2012; Kelemen, 2012). Indeed, the developmental trajectory of these construals—whether they are replaced, transformed, or merely inhibited—becomes an important question with implications for both our understanding of conceptual development and our thinking about science education. For example, Shtulman and Valcarcel (2012) show that acquired knowledge masks rather than replaces intuitive theories and ways of thinking across a range of scientific domains. They tested college undergraduates and had them indicate whether 200 statements about various natural phenomena from 10 different domains of knowledge were true or false as quickly as possible. Some statements were consistent across both intuitive and scientific theories, and some were not. On statements whose answers were inconsistent across intuitive and scientific theories, participants were less accurate and answered more slowly than on statements whose truth-value was consistent across the two theories. Their results suggest that intuitive thinking exerts a persistent conceptual influence, that intuitive ways of thinking may coexist with more formally acquired systems of knowledge or other explanatory systems (Legare, Evans, Rosengren, & Harris, 2012; Shtulman & Lombrozo, 2016), and consequently that developmental changes may be relatively superficial. As we review below, recent work with adults has productively informed our understanding of the development of teleological and essentialist thinking. Our goal in this paper is to apply a similar approach to anthropocentric reasoning. We argue that a detailed examination of adult anthropocentric thinking can elucidate both the underlying nature of this cognitive construal and its developmental trajectory.

Teleological thinking and essentialist thinking follow similar developmental trajectories. Both construals are evident early in development and utilized broadly, and both become more selective and restricted in scope with development. For example, young children are relatively “promiscuous” teleological thinkers, applying purpose-based
explanations to a wide range of phenomena, including natural objects (e.g., rocks are pointy “so animals won’t sit on them”), entire organisms (e.g., lions are “to look at in the zoo”), and biological parts (e.g., giraffes have long necks “so they can reach high leaves”; Kelemen, 1999, 2003, 2012). In contrast, older children and adults are much less likely to provide teleological explanations for natural objects and organisms, although teleological explanations for biological parts persist (Coley & Tanner, 2015; Kelemen, 1999; Kelemen & Rosset, 2009). Essentialist thinking broadly follows a similar trajectory. For example, preschoolers are less selective in their essentialist thinking than older children and adults. They tend to overestimate similarity to birth parents and underestimate environmental influences when attributing properties in a switched-at-birth task, whereas older children and adults are more likely to differentiate between physical properties (e.g., hair color or height) and psycho-behavioral properties (e.g., being good at math or believing in an afterlife), attributing the former to “nature” and the latter to “nurture” (Solomon, Johnson, Zaitchik, & Carey, 1996; Taylor, 1996; Taylor, Rhodes, & Gelman, 2009). Likewise, younger children tend to project a wide range of properties based on taxonomic category membership, whereas older children and adults restrict taxonomic inferences to intrinsic properties (Coley, 2012).

However, recent research with adults suggests the story may be more complex, and it indicates that teleological thinking and essentialist thinking may be “developmentally persistent cognitive defaults” (Kelemen, Rottman, & Seston, 2013, p. 1075): Although we may increasingly inhibit such intuitive thinking with development and with formal education, we never truly lose it. For example, undergraduates—and professional physical scientists—show an increased tendency to endorse scientifically incorrect teleological statements under time pressure (Kelemen & Rosset, 2009; Kelemen et al., 2013), and undergraduates make more essentialist responses about gender in a switched-at-birth task when under time pressure than when delayed (Eidson & Coley, 2014). These results suggest that development may involve the inhibition rather than the replacement of intuitive construal-based thinking. Similarly, Lombrozo, Kelemen, and Zaitchik (2007) tested teleology in young adults, healthy older adults, and adults with Alzheimer’s disease. They found that older adults with Alzheimer’s disease were significantly more likely than both the young adults and the healthy older adults to endorse teleological explanations, suggesting that when brain systems involved in memory and inhibition are compromised, it results in a greater tendency toward teleological thinking (or the “cognitive default”).

Anthropocentric thinking—like teleological and essentialist thinking—is an intuitive cognitive tool used to reason about biological phenomena. It involves extending one’s biological knowledge to other living and non-living things, based on their perceived similarity to humans. For example, one would be more likely to attribute a heart or the ability to think to a lion than to an ant, because a lion is seen as being more similar to a human than an ant is (Carey, 1985; Coley et al., 2017; Hermann, Waxman, & Medin, 2010; Inagaki, 1990; Inagaki & Hatano, 1991; Inagaki & Sugiyama, 1988; Ross, Medin, Coley, & Atran, 2003). Anthropocentric thinking has not been as widely studied as teleological or essentialist thinking, and there are conflicting theories as to its developmental trajectory and role in intuitive biological thought.
In one view, anthropocentric thinking is akin to teleological and essentialist thinking and is a universal component underlying intuitive biological thinking (Byrne, Grace, & Hanley, 2009; Carey, 1985; Inagaki & Hatano, 1987; Inagaki & Sugiyama, 1988). This means that young children are particularly susceptible to anthropocentric reasoning, either because their understanding of biological phenomena is essentially psychological in nature and humans are the prototypical possessors of psychological properties (Carey, 1985), or because reasoning by analogy to humans is particularly useful in the absence of specific knowledge about non-human organisms (Inagaki & Hatano, 1987). In line with this perspective, Byrne et al. (2009) found that children in the South of England, when asked to draw microorganisms and explain their drawings, often personified their drawings by adding features such as faces, expressions, and legs. In addition, they would describe those microorganisms in humanistic terms, such as “they just decide to be in something. They just think ‘I want to go’” (p. 41). Likewise, Inagaki and Hatano (1991) found that 5- and 6-year-old children frequently used humans as a reference point when making predictions about non-human living things (e.g., when estimating the effects of overeating on a grasshopper). From this perspective, anthropocentric thinking decreases as knowledge about living things is gathered and organized into a coherent framework (Carey, 1985; Geerdts, de Walle, Gretchen, & LoBue, 2015; Inagaki & Sugiyama, 1988).

In contrast, Waxman, Medin, and colleagues have argued that anthropocentric thinking is not a universal component of intuitive biological thinking, but rather a conceptual tool that reflects cultural patterns and environmental influence. For example, Ross et al. (2003) found that between ages 6 and 10, urban children showed increasing patterns of anthropocentric reasoning, whereas rural children showed decreasing patterns, and Native American children showed no evidence of anthropocentric thinking. Medin, Waxman, Woodring, and Washinawatok (2010) found similar results when comparing Rural European American, Urban European American, and Menominee children of different ages: Projection patterns and human-versus-dog base preference varied greatly between Urban European Americans and their Rural European American and Menominee counterparts, with only the Urban European American children showing evidence of anthropocentric thinking. They conclude that “culturally-held belief systems within the community appear to influence children’s reasoning about biological phenomena” (p. 9). Likewise, Hermann et al. (2010) modified Carey’s (1985) induction task to test children as young as three, and found that those 3-year-olds showed no preferential bias toward humans as an inferential base, suggesting a striking lack of anthropocentric thought as compared to their 5-year-old counterparts. These findings, taken together, suggest that anthropocentrism may not be a developmentally persistent cognitive default, but rather may be a culturally influenced cognitive strategy acquired later in development.

Anthropocentric thinking persists into adulthood, further suggesting that while knowledge may impact its use, it is not entirely discarded. For example, Coley and Tanner (2015) found evidence of anthropocentric explanations in both biology majors and non-biology majors, as did Hiatt et al. (2013) when they investigated college students’ reasoning about biological phenomena (see also Coley, 2007; Coley et al., 2017). This work
shows that undergraduates utilize anthropocentric thinking in some situations, but it does not address whether anthropocentric thinking is a developmentally persistent cognitive default or an acquired cognitive strategy. Beyond college-age students, Goldberg and Thompson-Schill (2009) showed that biology professors were slower and less accurate when categorizing plants as “living things” compared to animals. Their results suggest an anthropocentric hesitance, even among practicing biologists, to attribute universal biological properties to organisms that are highly dissimilar to humans.

However, to the best of our knowledge, no study has specifically examined the degree to which anthropocentric thinking, like teleological and essentialist thinking, represents a “developmentally persistent cognitive default.” If so, then we would expect anthropocentric reasoning to be inhibited by adults when appropriate, but to re-emerge under conditions that constrain the ability of the conceptual system to inhibit such thinking, as has been demonstrated for teleological thinking (Kelemen & Rosset, 2009; Kelemen et al., 2013), essentialist thinking (Eidson & Coley, 2014), and other intuitive beliefs (Shtulman & Harrington, 2016; Shtulman & Valcarcel, 2012).

In order to examine this possibility, we utilized a property projection task (Carey, 1985; Inagaki & Sugiyama, 1988; Ross et al., 2003) in which participants attributed a variety of properties to a wide range of living and non-living targets. On such tasks, similarity-based attribution patterns (i.e., gradual decreases in property attribution with decreasing similarity to humans) have been taken to indicate anthropocentric thinking (i.e., judging the likelihood of a shared property based on comparison to humans). In contrast, category-based attribution patterns (i.e., relatively high and uniform levels of attribution followed by a sharp drop in likelihood of shared properties) have been interpreted as indicating attributions based on higher order taxonomic categories rather than comparison to humans.

2. Study 1

In Study 1, we utilized the above-described task to examine the attribution patterns for a wide range of familiar biological and psychological properties. Critically, participants made attributions under speeded or delayed conditions. Based on previous findings that adults typically display category-based attribution patterns on such a task (e.g., Carey, 1985; Inagaki & Sugiyama, 1988), we expect to see the same patterns in the delayed condition of our task. Furthermore, if anthropocentric thinking is a developmentally persistent cognitive default that is inhibited in favor of other knowledge, we expect to see an increase in similarity-based responding in the speeded condition relative to the delayed condition. In contrast, if anthropocentric thinking is not a cognitive default, but rather a deliberately employed cognitive strategy, then we have no reason to expect time pressure to increase anthropocentric responding; in fact, it may interfere with the deliberate use of anthropocentric thinking.
2.1. Method

2.1.1. Participants

A total of 165 adults participated in this task; 45 completed a similarity task and 120 completed a property attribution task. Data gathered from five participants (two in the similarity task and three in the speeded condition of the property attribution task) were excluded for failure to follow instructions. This yielded a final total of 43 participants in the similarity task and 117 in the property attribution task (57 in the speeded condition and 60 in the delayed condition). All participants were Northeastern University undergraduates, and all received course credit for their participation. The experiment was approved by Northeastern University’s IRB.

2.1.2. Materials

We collected 300 images of plants, animals, and objects from various online sources; 30 images were drawn from each of 10 categories (human, mammal, bird, reptile, fish, insect, plant, natural object, complex artifact, and simple artifact). All images were either realistic drawings or photographs and had a neutral background. For purposes of randomization, images were arbitrarily divided into 30 sets of 10 images each (one image randomly chosen from each category).

2.1.3. Design

Participants completed either a similarity task or a property attribution task.

2.1.3.1. Similarity task: This task required participants to rate how similar each depicted category was to the category humans on a scale of 1 (Not Similar) to 10 (Very Similar). The 270 non-human images were divided into three sets of 90 images each (10 randomly chosen images from each of the nine categories). Each participant rated the images from a single set (in order to minimize fatigue), which were presented in a single randomly determined order. The directions asked the participants to rate the similarity of a plant, object, or animal (presented as an image) to a human on a scale from 1 to 10. Exact text can be found in the Supporting Information. Participants indicated their answer by clicking the bubble that represented that number. They then clicked a “next” button to advance the slide.

2.1.3.2. Property attribution task: Participants indicated whether a range of depicted objects and organisms held a variety of biological and psychological properties, presented in Table 1, that fell into three broad categories: universal biological properties (those necessarily shared by all living organisms), limited biological properties (characteristics that some, but not all, living organisms have in common), and psychological properties (characteristics that are known to exist in humans but are not always extended to non-human living organisms). Eight of the properties were based on those used by Inagaki and Sugiyama (1988); we added “Is X alive?” and “Can X reproduce?” to bolster the number of universal biological properties.
Participants viewed all 300 images individually. For each, they indicated whether the depicted category had one of the target properties. Participants read the property question and indicated when they were ready to proceed. Following this, three sets of 10 images (one from each of the 10 categories) were randomly presented with that property, for a total of 30 images for each question; property presentation was blocked. For each image, the participant indicated whether the depicted category had the queried property by hitting [F] for “yes” and [J] for “no.” The participants then moved on to the next question. Properties were presented in random order, and image sets were randomly assigned to properties for each participant.

For example, a participant would see the question “Does _____ have a heart?” appear on the screen. When they were ready, they clicked the “next” button to advance the task. At this point, an image, such as that of a monkey, would appear underneath the question, and the participants would select “yes” or “no” using a keystroke. The task would then advance automatically to the next picture, and this process would repeat for a total of 30 presentations of unique images. Once all 30 presentations had occurred, the next question would appear (e.g., “Can _____ feel pain?”), the participant would have the opportunity to read the question and then advance to the next slide, and the entire process would be repeated for another 30 unique images.

Half of the participants were tested in a speeded condition and half were tested in a delayed condition. In the speeded condition, in order to impose time pressure on responses we instructed participants to enter their response within 1.5 s of the presentation of each image. This restriction was based on previous work looking at the effect of time pressure on inferences (Shafto, Coley, & Baldwin, 2007) and on pretesting which suggested this was an interval at which participants experienced time pressure but could reliably respond. If they did not answer in time, they received an error message, and were prompted to respond more quickly. In the delayed condition, participants were required to wait 5 s following the presentation of each image before they could respond. This window, also based on pretesting, was determined to be considerably longer than a typical response latency.

2.1.4. Procedure

Both tasks were presented via computer using the Qualtrics web-based survey software package (Qualtrics, 2015). Participants were seated in front of a computer and encouraged to respond to each question thoughtfully. The directions instructed each participant to
reason about the category that each image represented (e.g., about the category “dog” when presented with an image of a dog, rather than exclusively reasoning about that particular dog). In the speeded condition, participants were instructed to answer questions within 1.5 s, and that the program would prompt an answer if they did not answer quickly enough. In the delayed condition, they were told they would need to wait 5 s before the program allowed them to proceed to the next question. Exact wording of the directions can be found in the Supporting Information. Participants read the directions at their own pace. Once they were ready, they were instructed to click the “next” button to begin the task. Each task then proceeded as described above. Upon completion, participants were thanked and debriefed.

2.2. Results

2.2.1. Analysis strategy

To analyze the similarity data, we conducted an item-wise 9 (Category) factorial ANOVA on mean similarity scores. To analyze the property attribution data, we ran 2 (Condition: speeded, delayed) x 9 (Target Category: mammals, birds, reptiles, fish, arthropods, plants, natural objects, complex artifacts, simple artifacts) mixed ANOVAs on attribution scores for each property. To characterize attribution patterns and identify “break points” in distributions, we conducted t-tests between adjacent target categories (e.g., mammal-bird, bird-reptile, reptile-fish, etc.), using a critical p-value of .006 to adjust for eight tests. Following Inagaki and Sugiyama (1988), we interpreted patterns of relatively stable attribution with a single large breakpoint as category-based patterns, and patterns of gradual decrease in attribute strength (or perceived similarity) lacking one salient “breakpoint” as similarity-based patterns (ostensibly driven by anthropocentric reasoning). We operationalized this logic by computing effect sizes for each pairwise comparison (using Cohen’s d, see Tables 2 and 4). We defined category-based inference patterns as having a single breakpoint that was large in both absolute (d ≥ 1.0) and relative (the effect must be at least twice as large as the next largest effect) terms. If no single difference stood out in both absolute and relative terms, we classified the attribution pattern as similarity based.

2.2.2. Similarity task

Participants rated each item on a scale of 1 (Not Similar to Humans) to 10 (Very Similar to Humans), and we averaged similarity ratings for each item. For the most part, exemplars were rated as relatively dissimilar to humans (mammals, with a mean of 6.01, were the only category rated higher than the midpoint of the scale). Target categories differed markedly in their perceived similarity to humans, F(8, 261) = 227.10, \( \eta^2=0.87, p < .001 \). Perceived similarity to humans decreased as a smooth linear function from mammals to simple artifacts (Fig. 1). Examination of effect sizes for pairwise comparisons of adjacent target categories (Table 2) revealed no single breakpoint in the distribution of similarity ratings. A total of four differences had effect sizes > 1.0 and the ratio of the largest effect (d = 2.017 for mammals vs. birds) to the second largest effect
<table>
<thead>
<tr>
<th>Property</th>
<th>Condition</th>
<th>Mam-Bird</th>
<th>Bird-Rep</th>
<th>Rep-Fish</th>
<th>Fish-Arth</th>
<th>Arth-Plant</th>
<th>Plant-NatObj</th>
<th>NatObj-CompObj</th>
<th>CompObj-SimpObj</th>
<th>Effect Size Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity to humans</td>
<td>N/A</td>
<td><strong>2.017</strong></td>
<td>1.637</td>
<td>.455</td>
<td>1.784</td>
<td>0.449</td>
<td>1.383</td>
<td>0.891</td>
<td>0.063</td>
<td>1.13</td>
</tr>
<tr>
<td>Grow</td>
<td>Delayed</td>
<td>0.074</td>
<td>0.074</td>
<td>0.091</td>
<td>0.227</td>
<td>0.081</td>
<td><strong>2.026</strong></td>
<td>0.824</td>
<td>0.129</td>
<td>2.46</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.074</td>
<td>0.000</td>
<td>0.074</td>
<td>0.000</td>
<td>0.088</td>
<td><strong>2.075</strong></td>
<td>0.616</td>
<td>0.048</td>
<td>3.37</td>
</tr>
<tr>
<td>Reproduce</td>
<td>Delayed</td>
<td>0.000</td>
<td>0.129</td>
<td>0.000</td>
<td>0.057</td>
<td>0.407</td>
<td><strong>2.080</strong></td>
<td>0.129</td>
<td>0.184</td>
<td>5.11</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.000</td>
<td>0.129</td>
<td>0.129</td>
<td>0.184</td>
<td>0.582</td>
<td><strong>2.107</strong></td>
<td>0.214</td>
<td>0.129</td>
<td>3.62</td>
</tr>
<tr>
<td>Alive</td>
<td>Delayed</td>
<td>0.141</td>
<td>0.218</td>
<td>0.199</td>
<td>0.338</td>
<td>0.088</td>
<td><strong>3.171</strong></td>
<td>0.443</td>
<td>0.227</td>
<td>7.16</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.048</td>
<td>0.074</td>
<td>0.057</td>
<td>0.000</td>
<td>0.370</td>
<td><strong>3.268</strong></td>
<td>0.323</td>
<td>0.091</td>
<td>8.83</td>
</tr>
<tr>
<td>Breathe</td>
<td>Delayed</td>
<td>0.227</td>
<td>0.105</td>
<td>0.137</td>
<td>0.337</td>
<td>0.461</td>
<td><strong>1.217</strong></td>
<td>0.000</td>
<td>0.227</td>
<td>2.64</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.000</td>
<td>0.129</td>
<td>0.214</td>
<td>0.129</td>
<td>0.589</td>
<td><strong>1.597</strong></td>
<td>0.129</td>
<td>0.074</td>
<td>2.71</td>
</tr>
<tr>
<td>Heart</td>
<td>Delayed</td>
<td>0.129</td>
<td>0.235</td>
<td>0.126</td>
<td>0.438</td>
<td>0.185</td>
<td><strong>0.901</strong></td>
<td>0.138</td>
<td>0.210</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.074</td>
<td>0.218</td>
<td>0.105</td>
<td>0.551</td>
<td>0.196</td>
<td><strong>0.342</strong></td>
<td>0.043</td>
<td>0.227</td>
<td>3.57</td>
</tr>
<tr>
<td>Bones</td>
<td>Delayed</td>
<td>0.164</td>
<td>0.579</td>
<td>0.374</td>
<td><strong>1.888</strong></td>
<td>0.541</td>
<td>0.129</td>
<td>0.129</td>
<td>0.129</td>
<td>3.26</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.039</td>
<td>0.498</td>
<td>0.285</td>
<td><strong>1.476</strong></td>
<td>0.732</td>
<td>0.129</td>
<td>0.000</td>
<td>0.129</td>
<td>2.02</td>
</tr>
<tr>
<td>Pain</td>
<td>Delayed</td>
<td>0.184</td>
<td>0.218</td>
<td>0.074</td>
<td>0.215</td>
<td><strong>2.638</strong></td>
<td>0.294</td>
<td>0.129</td>
<td>0.129</td>
<td>8.97</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.129</td>
<td>0.184</td>
<td>0.094</td>
<td>0.377</td>
<td><strong>1.327</strong></td>
<td>0.598</td>
<td>0.214</td>
<td>0.129</td>
<td>2.22</td>
</tr>
<tr>
<td>Think</td>
<td>Delayed</td>
<td>0.057</td>
<td>0.184</td>
<td>0.296</td>
<td>0.317</td>
<td><strong>1.778</strong></td>
<td>0.105</td>
<td>0.057</td>
<td>0.184</td>
<td>5.61</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.257</td>
<td>0.060</td>
<td>0.000</td>
<td>0.505</td>
<td><strong>1.268</strong></td>
<td>0.372</td>
<td>0.074</td>
<td>0.184</td>
<td>2.51</td>
</tr>
<tr>
<td>Communicate</td>
<td>Delayed</td>
<td>0.057</td>
<td>0.323</td>
<td>0.322</td>
<td>0.000</td>
<td><strong>1.937</strong></td>
<td>0.199</td>
<td>0.353</td>
<td>0.438</td>
<td>4.42</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.184</td>
<td>0.364</td>
<td>0.000</td>
<td>0.180</td>
<td><strong>1.450</strong></td>
<td>0.706</td>
<td>0.224</td>
<td>0.274</td>
<td>2.05</td>
</tr>
<tr>
<td>Happy</td>
<td>Delayed</td>
<td>0.353</td>
<td>0.502</td>
<td>0.094</td>
<td>0.486</td>
<td><strong>0.676</strong></td>
<td>0.260</td>
<td>0.074</td>
<td>0.074</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.362</td>
<td>0.417</td>
<td>0.380</td>
<td>0.436</td>
<td><strong>0.695</strong></td>
<td>0.371</td>
<td>0.074</td>
<td>0.184</td>
<td>1.59</td>
</tr>
</tbody>
</table>

*Note.* Bold entries represent the largest effect size for that property/condition.
(henceforth, “effect size ratio”) was only 1.13. Thus, somewhat reassuringly, similarity judgments met our criteria for a similarity-based response pattern and confirmed the ordering of target category stimuli with respect to similarity to humans.

2.2.3. Property attribution task

Each participant responded “yes” or “no” to 300 items (3 exemplars of each target category x 10 target categories x 10 properties). We quantified performance by summing the number of positive responses each participant gave to each target category for each property. This could range from 0 to 3, with higher numbers representing stronger attributions of the property to the target class. We were particularly interested in whether time pressure resulted in an increase in anthropocentric thinking, as indicated by more similarity-based inference patterns in the speeded condition. We report analyses by subject; all results reported below were also significant by item.

2.2.3.1. Universal biological properties: Response patterns for the three universal biological properties were similar and are depicted in Fig. 2. Attributions varied by target category for Does X Grow ($F(8, 944) = 1180.84, \eta^2 = 0.91, p < .001$, Fig. 2A), Does X Reproduce ($F(8, 944) = 1,161.33, \eta^2 = 0.91, p < .001$, Fig 2B), and Is X Alive ($F(8, 944) = 1,591.04, \eta^2 =0.93, p < .001$, Fig 2C). Participants attributed all three properties to animals and plants at near ceiling levels (although attributions of reproduction to plants...
were somewhat lower than for animals, see Fig. 2B), and rarely did so for natural objects or artifacts (although growth was attributed to natural objects more than to artifacts, likely due to the presence of some targets [e.g., clouds, hurricanes, tornados] that might reasonably be said to “grow,” and accordingly, to which participants were relatively likely to attribute growth, see Fig. 2A).

There was no effect of time pressure on attributions of Grow or Reproduce, but we did observe an interaction between time pressure and target for Alive, $F(8, 944) = 2.05$, $\eta^2 = .001, p = .038$ (Fig. 2C). Further analysis showed that aside from the persistent difference in attributions to plants and natural objects in the speeded condition (but not the delayed condition), participants were more likely to attribute life to arthropods than to

---

**Fig. 2.** Study 1: Mean number of positive responses (out of a possible 3) for each target category for universal biological properties. *Note:* Error bars represent 95% confidence intervals. Points connected by dotted lines differed reliably via *t*-test ($p < .006$); points connected by solid lines did not.
plants \((t(59) = 2.87, d = 0.37, p = .006)\), whereas in the delayed condition (but not the speeded condition), participants were more likely to attribute life to natural objects than to complex artifacts \((t(59) = 3.44, d = 0.44, p = .001)\). 

Examination of effect sizes for pairwise comparisons of adjacent target categories (Table 2) reveals that in all six cases, attribution patterns were clearly category based; in each case, we observed a single major breakpoint with an effect size larger than 1.0, between plants and natural objects \((d \text{ ranged from 2.026 to 3.268})\), and in all cases, the effect size ratio was > 2.0 (ranging from 2.46 to 8.83). Thus, although time pressure led to a slightly different pattern of attributions for Is X Alive, it did not result in an increase in similarity-based responding for any universal biological property.

2.2.3.2. Limited biological properties: Response patterns for the three limited biological properties were also similar and are depicted in Fig. 3. Attributions varied by target category for Does X Breathe \((F(8, 944) = 738.51, \eta^2 = 0.86, p < .001, \text{ Fig. 3A})\), Does X Have a Heart \((F(8, 944) = 1,055.42, \eta^2 = 0.90, p < .001, \text{ Fig. 3B})\), and Does X Have Bones \((F(8, 944) = 786.82, \eta^2 = .87, p < .001, \text{ see Fig. 3C})\). Participants attributed Breathe to animals at near ceiling levels, to plants at lower levels, and almost never did so for natural objects or artifacts (Fig. 3A). Similarly, they attributed Heart at near ceiling levels to mammals through fish; attributions decreased somewhat for arthropods, and then dropped dramatically for plants and non-living things, which did not differ (Fig. 3B). Attributions of Bones were high for higher animals, much lower for arthropods, and virtually zero for plants and all three groups of non-living things (Fig. 3C). One anomalous data point evident in Fig. 3C is for reptiles, to which bones were attributed at an unexpectedly low rate. Close examination of the target items revealed that 9 of the 30 reptile items were snakes. This raised the suspicion that the anomaly might stem from the mistaken belief that snakes do not have bones. To test this, we compared the percentage of positive attributions for snake items \((N = 9)\) versus non-snake items \((N = 21)\) in a 2 (Snake) \(\times\) 2 (Condition) ANOVA. Our suspicions were confirmed; bones were less likely to be attributed to snakes \((M = 85\%)\) than non-snakes \((M = 94\%), F(1, 28) = 7.10, \eta^2 = 0.20, p = .013\).

There was no effect of time pressure for Heart or Bones, but we did observe a main effect of time pressure for Breathe; overall, participants made more positive attributions in the speeded condition than in the delayed condition, \(F(1, 118) = 5.14, \eta^2 = .04, p = .025\). The interaction was not reliable.

Examination of effect sizes for pairwise comparisons of adjacent target categories (Table 2) reveals that again, in all six cases, attribution patterns were clearly category based, involving a single major breakpoint with an effect size larger than 1.0 (between plants and natural objects for Breathe, arthropods and plants for Heart, and fish and arthropods for Bones), with \(d\) ranging from 1.217 to 1.969, and an effect size ratio ranging from 2.02 to 4.22. Thus, although time pressure led to more attributions for Does X Breathe, it did not result in an increase in similarity-based responding for any limited biological property.
2.2.3.3 Psychological properties: Response patterns for psychological properties are depicted in Fig. 4. Results for Can X Feel Pain, Does X Think, and Can X Communicate were similar and are presented together; results for Can X Feel Happy are quite distinct, and we present those separately.

Attributions varied by target category for Can X Feel Pain, (F(8, 944) = 738.51, \( \eta^2 = 0.90 \), \( p < .001 \), Fig. 4A), Does X Think (F(8, 944) = 509.81, \( \eta^2 = 0.81 \), \( p < .001 \), Fig. 4B), and Can X Communicate (F(8, 944) = 637.88, \( \eta^2 = 0.84 \), \( p < .001 \), Fig 4C). In all three cases, participants attributed the properties to animals, but not to plants or non-living objects. We also observed a reliable target x condition interaction for Pain (F(8, 944) = 6.10, \( \eta^2 = .005 \), \( p < .001 \), Think (F(8, 944) = 2.04, \( \eta^2 = 0.003 \), \( p = .039 \), and

Fig. 3. Study 1: Mean number of positive responses (out of a possible 3) for each target category for limited biological properties. Note: Error bars represent 95% confidence intervals. Points connected by dotted lines differed reliably via t-test (\( p < .006 \)); points connected by solid lines did not.
Communicate ($F(8, 944) = 5.09, \quad \eta^2 = 0.007, \quad p < .001$). For all three properties, participants in the delayed condition only distinguished between animals and non-animals in their attributions. In contrast, those in the speeded condition evinced a more graded attribution pattern, attributing the ability to think and feel pain more to fish than arthropods (for Pain and Think), and more to plants than natural objects (for all three), in addition to the large difference between arthropods and plants (see Figs. 4A–C).

Based on examination of effect sizes, attribution patterns for all three properties were strongly category-based in the delayed condition, with a single large effect ($d = 1.778–2.638$) and effect size ratios ranging from 4.42 to 8.97 (Table 2). In contrast, although the pattern of effect sizes in the speeded condition is also consistent with a category-
based inference patterns (all three properties had a single large effect, $d = 1.268–1.450$, and effect size ratios ranged from 2.05 to 2.51), that pattern was attenuated in the direction of similarity-based inferences relative to the patterns observed in the delayed condition. Specifically, for all three properties, the single large effect was considerably weaker, and the effect size ratio was considerably smaller in the speeded condition than in the delayed condition (see Table 2). Thus, for attributions about the capacity to feel pain, think, and communicate, time pressure seems to have reduced the tendency toward strong category-based responding.

The attribution pattern for Can X Feel Happy was markedly different from any other property. Although still varying by target, $F(8, 944) = 214.85, \eta^2 = 0.64, p < .001$, attributions for Happy were relatively high for mammals and birds and steadily declined through inanimate objects (Fig. 4D). In fact, except for non-living objects, each target category differed from the adjacent categories. There were no effects of time pressure. Examination of effect sizes in Table 2 confirms a clear similarity-based attribution pattern; for no pair did the effect size approach, let alone exceed, 1.0, and the largest effect size ratio was 1.59. In other words, for Happy, there was no single salient breakpoint in attributions. Rather, they decreased steadily with increasing distance from humans.

2.3. Discussion

If anthropocentric thinking is a developmentally persistent cognitive default that is typically inhibited in favor of other knowledge by adults but nevertheless lurking below the surface, we would expect to see category-based attribution patterns in the delayed condition and similarity-based responding in the speeded condition (or at least an increase in similarity-based responding relative to the delayed condition). For biological properties—both universal and limited—we did not observe this pattern. Response patterns were uniformly categorical; participants consistently and correctly distinguished between living and non-living things for universal biological properties, whereas the breakpoint varied for limited biological properties (living things for Breathe, animals for Heart, and vertebrates for Bones). Time pressure had no effect on attributions of Grow, Reproduce, Heart, or Bones, and although time pressure led to subtly different patterns of attribution of Alive and Breathe, it did not increase similarity-based attributions. In sum, for biological properties, our results provide no support for the hypothesis that anthropocentric thinking is a developmentally persistent cognitive default.

Responses for psychological properties patterned somewhat differently. For Happy, attributions were clearly similarity based and unaffected by time pressure, consistent with the use of anthropocentric reasoning. In contrast, for Pain, Think, and Communicate, attribution patterns in both delayed and speeded conditions were categorical, with major breakpoints between animals and other target categories. However, for these three properties, unlike biological properties, time pressure had the effect of weakening the category-based attribution pattern. Specifically, although inference patterns were still categorical in nature, time pressure increased the number of significant categorical break points and reduced discrepancies in effect size. These findings lend some support to the possibility that when reasoning about
psychological properties, anthropocentric thinking may have an increased impact on reason-
ing under time pressure, which is consistent with the idea that, in some cases, anthropocen-
tric thinking may be a cognitive default, albeit a relatively weak one.

Why does the pattern differ for biological versus psychological properties? Although
there is evidence that both children and adults may show different attribution patterns for
these property types (Coley, 1995), we propose that the difference stems not from the
biological versus psychological content per se, but rather from the fact that there is a sci-
centifically accepted “correct” answer for the biological items that our young adult partici-
pants are likely to be familiar with (snakes notwithstanding). In contrast, questions about
the psychological lives of non-human organisms seem less likely to have normative
responses. As such, anthropocentric thinking, that is, comparing the target species to the
paragon possessors of psychological properties—humans—in order to make a decision,
may be a reasonable strategy for making inferences about the likely distribution of prop-
erties under uncertainty. Indeed, consistent with this view, developmental evidence sug-
gests knowledge and experience can result in selective reduction in anthropocentric
thinking (Geerdts et al., 2015; Inagaki, 1990; Ross et al., 2003). To test the hypothesis
that anthropocentric reasoning is a strategy employed in the face of uncertainty, we
examined attribution patterns for novel properties in Study 2, thereby guaranteeing that
there is no normative response available to influence participant reasoning.

3. Study 2

In Study 2, we examined the basis for projecting novel biological, psychological, and
behavioral properties attributed to humans to non-human animals, plants, and objects. If
anthropocentric reasoning is a strategy for making decisions under uncertainty, we expect
attribution patterns for novel properties to be strongly similarity based, in contrast to the
categorical attribution patterns we observed in Study 1.

3.1. Method

3.1.1. Participants

A total of 74 participants completed the novel property attribution task. Five were dis-
carded for failure to follow directions, leaving 69 participants (34 males and 35 females).
All participants were undergraduate students, and all received course credit for their par-
ticipation. The experiment was approved by Northeastern University’s IRB.

3.1.2. Materials

All images used in this experiment are a subset of those used in Experiment 1. Each
participant viewed a total of 105 images (15 pictures from each of seven categories: marmal, bird, fish, reptile, insect, plant, simple artifact). We developed three versions of
novel biological, psychological, and behavioral properties (Table 3). Novel properties
were used to ensure that no pre-existing knowledge about the property could influence
the reasoning of the participants—there was no “correct” answer. Pretesting confirmed that properties were interpreted as intended.

3.1.3. Design

The 105 images were separated into three sets of 35 images (five images randomly selected from each of seven target categories). Properties were divided into six blocks, such that each block contained a distinct biological, psychological, and behavioral property (e.g., has dramid cells, feels pesh when in danger, reacts to contentment by chigging). Psychological and behavioral properties with similar content were not presented to the same participants. Each participant saw all images and one property block (i.e., 35 trials for each of three kinds of novel properties). Image set/property pairings were counterbalanced so that each picture set occurred with two different versions of each kind of property across participants.

3.1.4. Procedure

This task was presented via computer using the Qualtrics web-based survey software package (Qualtrics, 2015). After reading general instructions (see Supporting Information), participants were presented with three property blocks. Each block contained 35 trials; for each trial, the participant was presented with an image, the information that “Research has shown that across many different cultures and historical periods, most people X,” where X was one of the three novel properties, and a six-point likelihood scale (e.g., see Fig. 5). Participants were asked to click on the bubble that best described how likely they thought it was that the depicted organism or object held the property using a 6-item Likert scale. Blocks and images within each block were presented in random order.

3.2. Results

3.2.1. Scoring

Participants rated the likelihood that five exemplars of each target category would possess each property. For each participant, we calculated scores for each target category
Research has shown that across many different cultures and historical periods, when they are in danger, most people feel *pesh*.

How likely do you think it is that _______ feel *pesh* when they are in danger?

![Sample item from Study 2.](image)

### 3.2.2. Effects of property and target category

Overall, mean likelihood ratings for novel biological ($M = 3.4$) and psychological ($M = 3.3$) properties did not differ, but both were higher than ratings for novel behavioral properties ($M = 2.9$), $F(2, 112) = 17.17, p < .001, \eta^2 = 0.24$, Tukey HSD (honest significant difference) $p < .001$. Mean likelihood ratings also varied by target, $F(6, 336) = 276.40.33, \eta^2 = 0.83, p < .001$. As can be seen in Fig. 6, likelihood ratings...
decreased steadily from mammals to artifacts. Finally, attribution patterns also differed somewhat by property, as indicated by a significant interaction, $F(12, 672) = 7.68, p < .001, \eta^2 = 0.12$; specific differences are depicted in Fig. 6. Examination of effect sizes revealed no single salient breakpoint for any of the three types of properties. For novel biological properties, two effects exceeded 1.0 in size (see Table 4), and the effect size ratio was only 1.1. For novel psychological properties, although only the difference between arthropods and plants exceeded 1.0 ($d = 1.124$), the effect size ratio was only 1.4 (see Table 4). Finally, for novel behavioral properties, no difference yielded an effect size of $> 1.0$. Although plants-arthropods approached this threshold ($d = 0.968$), the effect size ratio was only 1.19 (see Table 4). In other words, attribution patterns for all three novel properties were clearly similarity based.

### 3.3. Discussion

These results present a striking contrast with those of Study 1. In Study 1, participants clearly demonstrated strongly categorical attribution patterns for familiar biological properties and most familiar psychological properties. In Study 2, participants clearly demonstrated strongly similarity-based attribution patterns for novel biological, psychological, and behavioral properties. This similarity-based pattern suggests that participants were using anthropocentric reasoning to make inferences about novel properties of non-human
Table 4  
Effect sizes (Cohen’s $d$) and effect size ratio (largest effect/next largest effect) for pairwise comparisons of adjacent target categories, by property and condition, Studies 2–4

<table>
<thead>
<tr>
<th>Property</th>
<th>Condition</th>
<th>Mam-Bird</th>
<th>Bird-Rep</th>
<th>Rep-Fish</th>
<th>Fish-Arth</th>
<th>Arth-Plant</th>
<th>Plant-Art</th>
<th>Effect Size Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novel biological</td>
<td>N/A</td>
<td>1.039</td>
<td>0.444</td>
<td>0.069</td>
<td>0.597</td>
<td>0.657</td>
<td>1.133</td>
<td>1.09</td>
</tr>
<tr>
<td>Novel psychological</td>
<td>N/A</td>
<td>0.714</td>
<td>0.377</td>
<td>0.578</td>
<td>0.337</td>
<td>1.124</td>
<td>0.789</td>
<td>1.42</td>
</tr>
<tr>
<td>Novel behavioral</td>
<td>N/A</td>
<td>0.541</td>
<td>0.248</td>
<td>0.678</td>
<td>0.208</td>
<td>0.968</td>
<td>0.812</td>
<td>1.19</td>
</tr>
<tr>
<td>Study 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novel biological</td>
<td>Delayed</td>
<td>0.568</td>
<td>0.142</td>
<td>0.349</td>
<td>0.399</td>
<td>0.328</td>
<td>0.534</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.405</td>
<td>0.370</td>
<td>0.146</td>
<td>0.368</td>
<td>0.516</td>
<td>0.690</td>
<td>1.34</td>
</tr>
<tr>
<td>Novel psychological</td>
<td>Delayed</td>
<td>0.334</td>
<td>0.557</td>
<td>0.246</td>
<td>0.542</td>
<td>0.700</td>
<td>0.477</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.522</td>
<td>0.245</td>
<td>0.267</td>
<td>0.424</td>
<td>0.829</td>
<td>0.493</td>
<td>1.59</td>
</tr>
<tr>
<td>Novel behavioral</td>
<td>Delayed</td>
<td>0.377</td>
<td>0.517</td>
<td>0.324</td>
<td>0.384</td>
<td>0.584</td>
<td>0.296</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.250</td>
<td>0.237</td>
<td>0.111</td>
<td>0.310</td>
<td>0.937</td>
<td>0.268</td>
<td>3.02</td>
</tr>
<tr>
<td>Study 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grow</td>
<td>Delayed</td>
<td>0.106</td>
<td>0.075</td>
<td>0.169</td>
<td>0.291</td>
<td>0.040</td>
<td>3.420</td>
<td>11.75</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.000</td>
<td>0.189</td>
<td>0.000</td>
<td>0.215</td>
<td>0.401</td>
<td>4.970</td>
<td>12.39</td>
</tr>
<tr>
<td>Heart</td>
<td>Delayed</td>
<td>0.000</td>
<td>0.206</td>
<td>0.438</td>
<td>0.295</td>
<td>1.603</td>
<td>0.132</td>
<td>3.66</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.272</td>
<td>0.108</td>
<td>0.108</td>
<td>0.581</td>
<td>2.279</td>
<td>0.693</td>
<td>3.29</td>
</tr>
<tr>
<td>Think</td>
<td>Delayed</td>
<td>0.230</td>
<td>0.220</td>
<td>0.240</td>
<td>0.479</td>
<td>1.155</td>
<td>0.760</td>
<td>1.52</td>
</tr>
<tr>
<td></td>
<td>Speeded</td>
<td>0.269</td>
<td>0.169</td>
<td>0.118</td>
<td>0.377</td>
<td>1.828</td>
<td>0.367</td>
<td>4.85</td>
</tr>
</tbody>
</table>

*Note.* Bold entries represent the largest effect size for that property/condition.
species. These results reinforce the possibility that anthropocentric reasoning may represent a cognitive strategy for making inferences about novel properties.

However, other factors may have been responsible for the different results in Studies 1 and 2. First, Study 1 required a binary response (yes/no), whereas participants in Study 2 responded via a 6-point scale. Although similarity-based response patterns are not precluded by a binary response format (Happy in Study 1), perhaps the 6-point scale used in Study 2 encouraged more similarity-based responding, or the binary response scale in Study 1 encouraged more categorical responding. We investigate this possibility in Study 3.

Another alternative explanation is that we explicitly mentioned that the novel property was true of humans in Study 2, but not that the familiar property was true of humans in Study 1. Although the use of novel properties requires some potential basis for inference to be provided, perhaps explicit attribution of the novel properties to humans in the question encouraged comparison to humans and therefore increased similarity-based responding. We investigate this possibility in Study 4.

4. Study 3

Study 3 was designed to examine whether response format could account for the different attribution patterns in Studies 1 and 2. To do so, we presented the questions about novel properties from Study 2 in the binary response format of Study 1. If response format was responsible for the shift to similarity-based attributions in Study 2, then we should see an increase in category-based inferences in Study 3, which required a yes/no binary response rather than use of a likelihood scale. In contrast, if response format is irrelevant, similarity-based attributions should persist in Study 3. We also manipulated time pressure as in Study 1 to examine potential effects on attribution of novel properties, although we had no specific predictions.

4.1. Method

4.1.1. Participants

A total of 157 people participated in this study; 14 were discarded due to failure to follow instructions, leaving 143 participants (43 males and 100 females). Seventy-three were assigned to the delayed condition, and 70 were assigned to the speeded condition. All participants were undergraduate students, and all received course credit for their participation. The experiment was approved by Northeastern University’s IRB.

4.1.2. Materials and design

Materials for this task were identical to those used in Study 2, except that participants use the [F] and [J] keys to respond “yes” or “no,” respectively, rather than using the mouse to provide likelihood ratings. The design of this task was identical to that of Study 2, except that participants were randomly assigned to a speeded or delayed condition. As
in Study 1, participants in the speeded condition were required to respond within 1.5 s, whereas participants in the delayed condition had to wait for 5 s before responding.

4.1.3. Procedure
This task was presented via computer using the Qualtrics web-based survey software package (Qualtrics, 2015). Verbatim instructions can be found in the Supporting Information. The procedure was identical to that used in Study 1.

4.2. Results
4.2.1. Scoring
For each of three unfamiliar properties (biological, psychological, behavioral), participants made a binary yes/no decision about whether each of five exemplars of each target category would possess that property, responding under time pressure or delay. For each participant, we calculated the number of positive attributions for each target category and property, with a possible range of 0–5. To examine how attribution patterns varied by category and condition, we conducted separate 2 (Condition: delayed, speeded) 9 7 (Target Category: mammals, birds, reptiles, fish, arthropods, plants, artifacts) mixed ANOVAs on attribution scores. We used the same criteria as above for identifying category-based and similarity-based attribution patterns, and we compared adjacent target categories using a critical p-value of .008 to adjust for six tests. We are particularly interested in whether reasoning about unfamiliar properties using a binary response format follows the similarity-based patterns seen in Study 2, and whether time pressure has an impact on attributions of unfamiliar properties. Once again, we report analyses by subject; all results reported below were also significant by item.

4.2.2. Novel biological properties
Attributions of novel biological properties varied by target, F(6, 846) = 147.12, p < .001, η² = 0.51, decreasing steadily from mammals to artifacts. Overall, participants were more likely to attribute novel biological properties in the speeded condition than in the delayed condition, F(1, 141) = 6.22, p = .014, η² = 0.04, and attribution patterns also differed as a function of time pressure, as indicated by a significant target category × condition interaction, F(6, 846) = 2.41, p = .026, η² = 0.008. For delayed participants, all adjacent target categories differed except for birds and reptiles (Fig. 7A), and examination of effect sizes revealed no single salient breakpoint; no effect approached d = 1.0, and the effect size ratio was only 1.1 (Table 4). For speeded participants, all adjacent target categories differed except for reptiles and fish (Fig. 7A), and again, there was no single salient breakpoint; no effect approached d = 1.0, and the effect size ratio was only 1.3 (Table 4). Despite the similar attribution patterns in both conditions, attributions were significantly higher for speeded participants than for delayed participants for fish (t(141) = 2.41, p = .017, d = 0.40) and for arthropods (t(141) = 3.09, p = .002, d = 0.52). In sum, attribution patterns for novel biological properties in a binary response mode were clearly similarity-based.
4.2.3. Novel psychological properties

Attributions of novel psychological properties also varied by target, \( F(6, 846) = 244.20, p < .001, \eta^2 = 0.63 \). Likelihood ratings decreased steadily from mammals to artifacts, and all adjacent target categories differed from each other significantly (Fig. 7B). There were no effects of time pressure on attributions of novel psychological properties. Examination of effect sizes (Table 4) reveals that the attribution pattern was again clearly similarity based; no single breakpoint existed. All effects were well below 1.0, and the effect size ratio was 1.6.

Fig. 7. Study 3: Mean number of positive responses (out of a possible 5) for each target category sharing a novel biological (A), psychological (B), or behavioral (C) property with humans. *Note:* Error bars represent 95% confidence intervals. Points connected by dotted lines differed reliably via \( t \)-test \((p < .008)\); points connected by solid lines did not.
4.2.4. Novel behavioral properties

Attributions for novel behavioral properties varied by target, $F(6, 846) = 165.31, p < .001, \eta^2 = .53$. As can be seen in Fig. 7C, likelihood ratings decreased from mammals to artifacts. Although there was no overall effect of time pressure, this variable did interact with target category ($F(6, 846) = 4.22, p < .001, \eta^2 = 0.01$) indicating different patterns of attribution in the delayed and speeded conditions. For delayed participants, no single breakpoint stands out. All adjacent target categories except for plant-artifact differed from each other (Fig. 7C), the largest effect was well below 1.0 (arthropod-plant, $d = 0.584$) and the effect size ratio was 1.1 (Table 4). In contrast, for participants under time pressure, there was a single salient breakpoint in the pattern of attributions (Fig. 7C). The only significant difference between adjacent target categories was for arthropod-plant ($d = 0.937$), and this difference was large both absolutely (approaching 1.0) and relatively (effect size ratio = 3.02, see Table 4).

4.3. Discussion

The results of Study 3 clearly show that the similarity-based patterns observed in Study 2 were not an artifact of the response scale. In five out of six conditions, participants reproduced similarity-based attribution patterns in a binary response format. Like the results of Study 2, these present a striking contrast with those of Study 1. Participants clearly demonstrated strongly similarity-based attribution patterns for novel biological, psychological, and behavioral properties. This similarity-based pattern suggests that participants were using anthropocentric reasoning to make inferences about novel properties of non-human species and reinforce the possibility that anthropocentric reasoning may guide inferences in the face of uncertainty.

Results of Study 3 also extend those of Study 2 by examining the effects of time pressure on attribution patterns for novel properties. Recall our logic for examining time pressure; if anthropocentric thinking represents a developmentally persistent cognitive default for making inferences, then anthropocentric response patterns should emerge more strongly under time pressure, when participants may lack the resources to inhibit their default response. Results of Study 3 suggest that this is not the case. For novel biological and psychological properties, time pressure had little effect on responses, and no effect on the similarity-based nature of attribution patterns. For novel behavioral properties, time pressure had a much stronger effect on attribution patterns; however, it was precisely the opposite effect. Delayed participants’ attributions about novel behavioral properties were clearly similarity based, whereas speeded participants produced categorical attributions. These results lend further support to the proposition that anthropocentric reasoning may be a deliberate cognitive strategy used in the face of uncertainty, rather than a developmentally persistent cognitive default inhibited by later learning.

Although these results would seem to rule out the possibility that the differences between Studies 1 and 2 were due to differing response modalities, another alternative explanation is that similarity-based inference patterns were elicited by the fact that we
explicitly attributed the property to humans in the questions for Studies 2 and 3, but not for Study 1. Perhaps, explicit attribution of the novel properties to humans in the question encouraged comparison to humans and therefore increased similarity-based responding. We investigate this possibility in Study 4.

5. Study 4

Because of the novelty of the properties presented in Studies 2 and 3, it was necessary to explicitly attribute them to humans. It is therefore possible that the mention of humans as a base triggered anthropocentric reasoning, rather than the novelty of the properties themselves. Because it was not possible to ask about novel properties without attributing them to something, we opted instead to ask about a subset of the known properties that showed strong category-based attribution patterns in Study 1, and to explicitly attribute them to humans in the question. If the explicit mention of humans as the inferential base increased similarity-based attribution, then we should also observe increased similarity-based responding for these known properties.

5.1. Method

5.1.1. Participants

A total of 75 participants completed this task; 11 were discarded due to failure to follow instructions, leaving 63 participants (30 males, 32 females, 1 other). Twenty-eight were assigned to the delayed condition, and 35 were assigned to the speeded condition. All participants were undergraduate students, and all received course credit for their participation. The experiment was approved by Northeastern University’s IRB.

5.1.2. Materials

Images used in this study were the same ones used in Studies 2 and 3. Three properties from Study 1 (Grow, Heart, Think) were used. Properties were framed to match Studies 2 and 3, and as such explicitly referenced the fact that these properties are generally true of humans (e.g., “Research has shown that across many different cultures and historical periods, most people grow.”).

5.1.3. Design

The design was similar to the preceding experiments. Property was manipulated within subjects, presentation was blocked, blocks were presented in random order, and participants attributed each property to a set of 35 target categories. Image sets were counterbalanced to appear with each property a comparable number of times. Within each block, images were presented in random order. Time pressure was manipulated between subjects. Speeded and delayed timing was identical to Studies 1 and 3.
5.1.4. Procedure

This task was presented via computer using the Qualtrics web-based survey software package (Qualtrics, 2015). Verbatim instructions can be found in the Supporting Information. Participants were shown all 105 images one at a time. For each image, they were asked to indicate whether the depicted organism or object had one of the target properties, just like a human did. Participants were asked to use the [F] and [J] keys to select “yes” or “no,” respectively.

5.2. Results and discussion

5.2.1. Scoring

For each of three familiar properties (Grow, Heart, Think), participants made a binary yes/no decision about whether each of five exemplars of each target category would possess that property, responding under time pressure or delay. For each participant, we calculated the number of positive attributions for each target category and property, with a possible range of 0–5. To examine how attribution patterns varied by category and condition, we conducted separate 2 (Condition: delayed, speeded) × 7 (Target Category: mammals, birds, reptiles, fish, arthropods, plants, artifacts) mixed ANOVAs on attribution scores. We again defined inference patterns as detailed above, and we conducted planned comparisons between adjacent target categories using a critical p-value of 0.008 to adjust for six tests. We are particularly interested in whether framing familiar properties as being true of humans increases similarity-based inference patterns for those properties relative to Study 1. Once again, we report analyses by subject; all results reported below were also significant by item.

5.2.2. Does X grow?

Attributions of growth varied by target category, \( F(6, 366) = 630.86, p < .001, \eta^2 = 0.91 \). As in Study 1, participants attributed growth to animals and plants at near ceiling levels, and almost never did so for artifacts (Fig. 8A). There was no effect of time pressure on attributions of growth. This attribution pattern was strongly categorical; only the plant-artifact comparisons were significant, the effect (d > 3.4) was well over 1.0, and the effect size ratio was well over 11 (Table 4).

5.2.3. Does X have a heart?

The attribution pattern for Heart varied by target, \( F(6, 366) = 386.15, p < .001, \eta^2 = 0.86 \). As in Study 1, attributions were near ceiling for mammals to fish, somewhat lower for arthropods, and dramatically lower for plants and artifacts (Fig. 8B). And as in Study 1, there was no reliable effect of time pressure. Again, the attribution pattern was strongly categorical; the effect for arthropods-plants (d > 1.6) was the only one over 1.0, and the effect size ratio exceeded 3.2, indicating a single major breakpoint in the distribution (Table 4).
5.2.4. Does X think?

The attribution pattern for *Think* varied by target, *F*(6,366) = 254.14, *p* < 0.001, $\eta^2 = 0.80$. As in Study 1, participants readily attributed the ability to think to animals, but not to plants or artifacts (Fig. 8C). Unlike in Study 1, there were no significant effects of time pressure. Again, the attribution pattern was clearly categorical. When the speeded and delayed conditions were considered together, only the difference for arthropod-plant ($d = 1.398$) exceeded 1.0, and the effect size ratio was 2.4.

In sum, even when the property was explicitly presented as being true of humans, attribution patterns for *Grow*, *Heart*, and *Think* were unequivocally category-based. This
strongly suggests that explicitly mentioning humans in the premise is not sufficient to explain the similarity-based inference patterns for novel properties observed in Studies 2 and 3.

6. General discussion

Our primary question was whether anthropocentric thinking—like teleological thinking and (perhaps) essentialist thinking—can be characterized as a “developmentally persistent cognitive default” (Kelemen et al., 2013). To address this question, we examined patterns of attribution of biological, psychological, and behavioral properties to a wide range of living and non-living targets, and manipulated whether attributions were made under time pressure or delayed. Our logic, following that of Kelemen et al. (2013), Eidson and Coley (2014), and others, was that if anthropocentric thinking was a persistent cognitive default that was inhibited with development, then young adults under time pressure should show increased levels of anthropocentric thinking, as manifest in similarity-based attribution patterns.

6.1. Anthropocentric thinking, although evident, is not a developmentally persistent cognitive default

Our results suggest that anthropocentric thinking is not a developmentally persistent cognitive default. We manipulated time pressure in three separate studies; out of 16 properties tested across those studies, none showed a shift from category-based to similarity-based inferences under time pressure. This was not because our manipulation of time pressure was ineffective; seven out of 16 instances showed some effect of time pressure. Rather, these results suggest that anthropocentric thinking—unlike teleological thinking (Kelemen & Rosset, 2009; Kelemen et al., 2013), essentialist thinking (Eidson & Coley, 2014), and other intuitive beliefs (Shtulman & Lombrozo, 2016; Shtulman & Valcarcel, 2012)—is not a developmentally persistent cognitive default that reemerges when the conceptual system is deprived of the resources to inhibit it.

However, we did observe clear evidence of anthropocentric reasoning in adults, in line with other work (e.g., Coley, 2007; Coley & Tanner, 2015; Coley et al., 2017; Goldberg & Thompson-Schill, 2009; Hiatt et al., 2013; Inagaki & Sugiyama, 1988). Specifically, our participants systematically employed similarity-based reasoning in situations where their knowledge was limited, such as when reasoning about known properties that did not have a scientifically factual answer (i.e., “Can X feel happy?” in Study 1) or about novel biological, psychological, and behavioral properties (Studies 2 and 3). Importantly, these attribution patterns were not determined by response format (Study 3) or explicit reference to humans (Study 4). Moreover, for inferences about novel behavior in Study 3, we observed a shift from similarity-based reasoning when delayed to category-based reasoning when speeded, suggesting that time pressure actually inhibited—rather than potentiated—anthropocentric thinking. These findings suggest that rather than being a
developmentally persistent cognitive default, anthropocentric thinking may be a cognitive strategy that is deliberately applied to guide inferences in the absence of more specific knowledge.

6.2. Implications for conceptual development and education

These findings have implications for our understanding of the development of intuitive biological concepts. Anthropocentric thinking, although clearly present in our participants, is not a “developmentally persistent cognitive default,” but rather a context-dependent cognitive strategy. This finding complements the view that anthropocentric thinking is not a universal feature of intuitive biological thought, but rather a phenomenon that emerges in particular cultural and environmental contexts (Hermann et al., 2010; Medin et al., 2010; Ross et al., 2003). As such, it seems likely that anthropocentric thinking is acquired through a combination of implicit learning via exposure to cultural practices that emphasize the uniqueness, importance, and centrality of humans in the natural world (e.g., parental input, books, media), and explicit learning or modeling of this strategy, perhaps even in the science classroom (e.g., Quinn, Castéra, & Clément, 2016). On this view, reports of widespread anthropocentric thinking in young urban and suburban children (e.g., Carey, 1985; Inagaki & Sugiyama, 1988; Ross et al., 2003) may result from these children being both (a) culturally exposed to anthropocentric thinking, making the cognitive strategy available, and (b) less familiar than older children about the normative distribution of biological properties, making the application of an available anthropocentric strategy likely.

More generally, these findings suggest that different cognitive construals underlying the intuitive biological thinking of Western adults may have distinct developmental origins and trajectories. Some, like essentialist or teleological thinking, may be developmentally persistent cognitive defaults, whereas others, like anthropocentric thinking, may be culturally transmitted cognitive strategies. If accurate, this developmental picture may have important implications for biology education. Coley and Tanner (2012, 2015) have argued that cognitive construals such as teleological, essentialist, and anthropocentric thinking may underlie systems of misconceptions spanning traditional biological topics (e.g., teleological thinking may give rise to misconceptions about evolution, cellular structure and function, and ecology). If anthropocentric thinking is a culturally transmitted and consciously applied strategy rather than a developmentally persistent (and perhaps universal) cognitive default, it suggests that anthropocentric misconceptions might be more variable among populations, and perhaps more easily rectified, than essentialist or teleological misconceptions which may arise from more deeply entrenched intuitive thinking.

6.3. Limitations and future directions

Our participants were all recruited from a single university in the northeastern United States and are of a limited age range. As such, our findings may not be generalizable to older adults or adults in other geographic areas. The limited impact of time pressure on
our findings may indicate that our manipulation was not stringent enough or that another manipulation (such as cognitive load) may produce a different result. We consider the first alternative to be unlikely; as mentioned above, we did repeatedly observe statistical effects of time pressure on responses, and supplemental analyses that restricted responses to those provided in shorter time frames did not substantially change our results; the latter hypothesis has not been tested and should be the subject of further research. Relatedly, our measures—which depended on the outcome of property attribution judgments—could be expanded to include response latency. Anthropocentric thinking might result in longer response times for targets of intermediate similarity to humans (i.e., those for which participants need to expend more effort to assess similarity) than for items that are clearly similar or clearly dissimilar to humans. Such a pattern might suggest that despite the categorical attribution patterns we observed for familiar properties, anthropocentric thinking had some impact on processing of responses.

Continued study in this area is warranted beyond the response time hypothesis mentioned above. Our examination is limited to a property projection task. However, anthropocentric thinking has been demonstrated using a variety of measures, including triad oddity tasks (Coley, 2007), qualitative coding of explanations (Coley & Tanner, 2015), and “common ancestor” tasks (Coley et al., 2017; Shtulman, 2006). These tasks may elicit different facets of this cognitive construal, such as anthropomorphism (attributing human qualities to non-human things), “human exceptionalism” (the tendency to see humans as biologically unique and discontinuous with the rest of the animal world; Gee, 2013), and the use of human artifact analogies when explaining biological concepts (e.g., “the brain is like a computer”). Therefore, additional research designed to understand other possible components of anthropocentric thinking is necessary. It is also important to examine the hypothesis among culturally diverse participants to assess the degree to which anthropocentric thinking in novel situations is a culturally bound versus widespread strategy.

6.4. Conclusions

Our findings suggest that anthropocentric thinking is not a developmentally persistent cognitive default. Rather, they support the idea that anthropocentric thinking is a cognitive strategy utilized in situations of uncertainty, such as when reasoning about questions without an agreed-upon correct answer or when presented with a novel property. This suggests that different aspects of intuitive thinking about biology may have different developmental origins and trajectories, which may in turn have implications for science education efforts to address misconceptions arising out of intuitive thinking.

Acknowledgments

Funding for this research was provided by the National Science Foundation grant number ECR-1535496, and by seed funding from the Northeastern University College of
Science Dean’s Office. We are grateful for the ideas, support, and intellectual community provided by the members of the Categorization and Reasoning Lab/Conceptual Organization, Reasoning and Education (CORE) Lab, and especially the contributions of Samantha Daoust, Grace Kreher, Kathryn Hardin, Jillian Book, Julia Hurley, Emma Pitt, and Alix Alto.

Note

1. Questions about behavioral properties of plants were inadvertently omitted for 12 participants. As such, these participants are omitted from the overall ANOVA, but they are included in the follow-up pairwise comparisons where possible.

References


### Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

**Data S1.** Verbatim participant instructions for Studies 1–4.