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Cognitive Constraints Influence the Understanding of Lifecycle Change

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A basic component of a folk biology is an understanding of what types of change occur naturally over the course of an organism's lifespan. At its core, this understanding focuses on the concept of growth; that animals over the course of their lives get larger and change in predictable ways (Rosengren, Gelman, Kalish, & McCormick, 1991). However, some patterns of life-cycle changes can be quite dramatic, involving drastic changes in appearance and behavior, such as when a caterpillar undergoes metamorphosis, becoming a butterfly. Examining how individuals reason about different patterns of life-cycle changes can provide insight into the development of intuitive reasoning concepts about the biological world and the extent to which such reasoning is influenced by underlying cognitive constraints. The main goal of the present study was to investigate how individuals reason about life-cycle changes and how judgments about the possibility of life-cycle change is influenced by age and familiarity with the biological organism.

Researchers have investigated several cognitive constraints that might influence reasoning about the natural world (e.g., anthropocentric and teleological reasoning, Arenson & Coley, 2017; Kelemen, 2012), and many have explored children's and adults' reasoning about biological organisms in terms of a particular constraint: psychological essentialism (Emmons & Kelemen, 2015; Gelman, 2003; Gelman & Rhodes, 2012; Shtulman & Shultz, 2008). Psychological essentialism refers to the notion that people act as if they hold an implicit belief that category membership is determined by an underlying essence (Medin & Ortony, 1989).

Gelman and colleagues (Gelman, 2003; Gelman & Rhodes, 2012) have proposed that essentialism is composed of a number of components, including: immutability (i.e., that an organism's biological category membership is stable over physical transformations), innate potential (i.e., that the developmental trajectory of an organism is fixed at birth), intensification of category boundaries (i.e., that category membership is binary), non-obvious causal properties (i.e., that unobservable properties are responsible for surface appearances), and inductive potential (i.e., that knowledge of category membership enables

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the generalization of inferences). These components are thought to structure the ways in which individuals think about the category membership of natural kinds (but see Bloom, 1999; Diesendruck, Markson, & Bloom, 2003). We argue that these components operate as different essentialistic constraints on reasoning at different levels of abstraction (Evans & Rosengren, in press). Few if any studies have investigated how these components explicitly influence biological reasoning about biological change and whether the individual components have different developmental trajectories. Thus, a further goal of this study was to chart their probable developmental course, by linking components of essentialism to different patterns of biological change.

Patterns of biological change: Identical growth, naturalistic growth, dramatic change, and species change

In previous research investigating children's beliefs about four different patterns of biological change, Rosengren and colleagues used a forced choice task to examine whether children understood that animals grow bigger over the life span (Rosengren, Gelman, Kalish, and McCormick, 1991; see also Inagaki & Hatano, 1996). Young children (3- to 4-year-olds) consistently responded that animals could get bigger over the life span, but generally did not accept that animals would change in other ways (e.g., in proportions, in color, or other features). We refer to this pattern of change as identical growth because the only feature that changes over the life span is physical size, on all other physical dimensions the juvenile and adult versions are expected to be the same. This pattern of growth does not normally occur, as organisms change in proportion as well in size.

The second pattern of change, which we refer to as naturalistic growth, involves changes in size and changes in physical proportions. This is the pattern of change that distinguishes juvenile and adult features (i.e., juveniles having softer, smaller, features and proportional differences). Lorenz (1971) argued that these features help infants of different species survive as they generally elicit affection, even from members of another species. It is this pattern of change that is used by orthodontists and anthropologists to model changes in facial features over growth (Thompson, Krovitz, & Nelson, 2003). It is a typical pattern of change for mammalian growth, such as puppies and kittens that grow and change proportionally into adult dogs and cats.

Rosengren et al (1991) found in a forced choice task that children only endorse changes other than a size increase if the alternative presented is perceived as impossible (i.e., an animal getting smaller over time). Herrmann, French, DeHart, and Rosengren (2013) found that while children's endorsement of naturalistic growth increases with age, it is also dependent on the number of features that vary. For example, children were more likely to endorse an animal changing in size and color than an animal changing in size, color, and shape. This result is consistent with Piaget's (1967) concept of identity constancy. Piaget (1967, pp. 27–29) referenced studies by Voyat in which children were presented with a chemical structure change in water, which resembled a growing plant. Children stated that the structure that grew over time was the "same plant" if it was presented over short periods of time and involved small changes in appearance. However, over a longer time frame and a greater degrees of change, children responded that the “plant” was no longer the same one.

The third pattern of change is dramatic change. The prototype of this change is metamorphosis, in which, for example, a caterpillar changes in size, texture, color, and body structure over development. In the forced choice task presented by Rosengren et al (1991) both children and adults generally responded as if an animal is more likely to grow larger than to undergo metamorphosis. Herrmann et al’s (2013) data support this research. In their study, preschool children only endorsed metamorphosis after they were exposed to a classroom demonstration of the life span of a butterfly. Even then, children only endorsed metamorphosis for the particular animal that was in the classroom presentation, and not others.

The final type of possible change is a non-biological species change, in which biological organisms change category membership over the life cycle. If children had no constraints on their reasoning about possible changes in the biological domain, they might be expected to accept this type of transformation. Previous research has shown low acceptance of species change at all points in development (DeVries, 1969; Keil,1989; Rosengren, Kalish, Hickling & Gelman, 1994).

Although several studies have explored children’s endorsement of these patterns (Herrmann et al., 2013; Rosengren et al., 1991), this is the first study to investigate how endorsement on of these patterns varies depending on age and familiarity with the animal. Additionally, we relate these patterns to the different components of essentialist reasoning to understand how the different components of essentialism emerge at different point in development.

Links between patterns of growth and components of essentialism

We argue that the different patterns growth relate to different components of psychological essentialism (See Table 1, for a summary). Endorsement of a naturalistic growth pattern indicates that a person assumes that innate potential (e.g., that organisms change in predictable ways over growth) operates over an animal’s life-span. Although there might also be an immutability constraint (e.g., that physical changes that occur over growth do not lead to a change in biological category), individuals’ tendency to only endorse small life cycle changes suggests that they still believe that drastic changes throughout life might lead to a category change.

As with the naturalistic growth pattern, participants endorsing dramatic patterns of change are assuming that innate potential and immutability constrain this growth pattern. For example, a participant must recognize not only that a caterpillar will turn into a butterfly, but also that the organism is not changing from one biological category to another as they undergo metamorphosis. Past work by Rosengren et al., (1991) found that three-year-olds, the youngest children tested, generally did not accept metamorphosis as a natural, biological change. We hypothesize that both the naturalistic growth and dramatic change patterns may be somewhat later developing and indicative of a more mature form of reasoning.

The species change growth pattern is unlikely to draw on any component of essentialism as it is not generally viewed as a natural, biological change. Indeed, this pattern of change has generally been presented in past research as a control condition to ensure that children are not merely accepting any type of change.

Endorsing the identical pattern of change may be indicative of an additional early emerging aspect of essentialism. We propose that this component reflects a featural stability bias in which participants reason that properties of an organism remain stable over time. By bias, we refer to a systematic tendency to respond in a particular manner to a particular type of stimuli or context based on relatively rapid, intuitive reasoning (for a similar view see: Evans, E. & Rosengren, in press; Kahenman, 2011). This has been referred to as System I reasoning (Evans, J. & Stanovich 2013). Although innate potential (Gelman, 2003) may constrain children's understanding of growth and inheritance, featural stability may be responsible for the rejection of more drastic changes in an individual organism over time. Whereas immutability refers to the intuition that individuals do not change categories, featural stability can be thought of as an extreme, or very early, version of the immutability constraint, in which children believe that organisms do not change at all as they grow, except in size. For example, in the research by Rosengren, Gelman, Kalish and McCormick (1991), the youngest children studied, 3-year-olds, endorsed growth for members of a particular biological category, but not dramatic change (e.g., metamorphosis). In a different set of investigations, the youngest children in DeVries' (1969) and Keil's (1989) transformation studies thought that changes in perceptual features led to changes in biological category membership, suggesting that featural stability is an important marker of living kind membership for young children. The results of these studies indicate that children's reasoning about biological change is constrained to some extent by an underlying bias that characteristics of a biological organism remain stable over time.

A bias to assume featural stability over time is also in line with research on individuals' underestimation of within-category variability (Emmons, & Kelemen, 2015). These authors suggest that children, in particular, underestimate how different members of a given category are from each other, called within-category variability, and assume that members of the same category will have identical features. This underestimation leads them to overestimate species coherence, and to exaggerate the distance between categories by intensifying category boundaries. In our current research, we investigate whether children show a similar bias. This bias, we argue, leads them to assume that little variation occurs over the life cycle, and that the features of an organism will not vary or change across its life – namely, the bias for featural stability. Thus, featural stability can be construed as an early emerging principle, which constrains both within-category variability and changes exhibited over the life span.

A similar line of research supports the link between components of essentialism and acceptance of different levels of featural change between parents and offspring (Shtulman & Schulz, 2008). In this research, participants were asked to judge the possibility of species-specific behavioral and anatomical properties across different members of the same species. For example, researchers told adults that giraffes had spots on their coats to blend into the savannah and then asked if giraffes could be born without spots on their coats. Shtulman and Schulz were able to differentiate participants who conceptualized species as collections of unique individuals versus those that characterized species as an instantiation of an underlying essence based on how much variability they allowed for within-species judgments (e.g., allowing that a giraffe could be born without spots). This study links essentialism to a bias for featural stability between parents and offspring, and within a species, that is at odds with the within-species variation present in the natural domain.

Similarly, a study by Rhodes and Gelman (2009) found that children treat biological categories as if they have rigid boundaries that do not incorporate atypical members. With age and increased knowledge of the category these atypical members are integrated into the category. A similar process might occur with children's endorsements of lifecycle change, where more drastic life span changes are initially rejected, but as children gain more experience with organisms that exhibit dramatic change, they may endorse a greater level of lifecycle change. We suggest that children may modify their featural stability bias as they become more familiar with the changes that specific organisms undergo over the life cycle. As this familiarity increases, children will come to accept the kinds of changes that occur in the growth and metamorphosis of species as part of the species' innate potential (Herrmann, et al., 2013).

Present Study

To our knowledge this is the first study to propose featural stability as a component of essentialist reasoning and to argue that different components of essentialism emerge at different points in development. Additionally, we argue that the different components of essentialism might operate at different levels of abstraction (Evans, & Rosengren, in press). In the current research, we compared the performance of three age-groups of children with that of college aged adults, in their endorsement of various parent-offspring relationships that captured the different growth patterns described earlier. The depicted organisms varied in familiarity and whether or not they undergo metamorphosis. Based on past research (Carey, 1985, 1991; Gelman, 2003; Keil, 1989; Rosengren, Gelman, Kalish, & McCormick, 1991), the age groups were chosen to varying degrees of formal biological instruction that might influence their knowledge of metamorphosis.

We predict differences in the endorsement of growth patterns as a function of age, familiarity and type of change. First, we propose that a bias for featural stability serves to initially constrain the range of possibilities that individuals are willing to consider with respect to changes in an organism over its life cycle. Based on this hypothesis we predicted young children to be more likely to endorse identical growth, only. We also predicted that identical growth might be the default model for individuals, even adults, when presented with species that were unfamiliar. Findings by Herrmann et al., (2013) support this prediction by indicating that children's reasoning about metamorphosis was influenced by direct experience. Our second prediction was that with increasing age and knowledge of the biological world, children would be more likely to endorse the naturalistic growth pattern. This pattern embraces some change in appearance, such as proportional changes in head and body size from infancy to adulthood. Based on a bias to assume featural stability, we do not expect that most children would endorse this type of model for unfamiliar species. Our third prediction was that with increasing age and knowledge both children and adults would accept dramatic changes, such as those that occur in metamorphosis, but only for those species that were relatively familiar.

Method

Participants

One hundred twenty children (72 females, 48 males) were recruited through community schools and contacts in a midsize city in the Midwestern United States. The total sample was divided into age groups of 3–5-year-olds (n = 41, M_{age} = 4 years, 7 months, age range: 3 years 8 months to 5 years 10 months, sex: 23 females, 18 males), 6–8 year-olds (n = 40, M_{age} = 7 years, 11 months, age range: 6 years, 3 months to 8 years 9 months, sex: 26 females, 14 males), and 9–11 year-olds (n = 29, M_{age} = 9 years, 8 months, age range: 9 years, 1 month to 11 years, sex: 18 females, 11 males). Eighteen adults (M_{age} = 21.3 years, age range: 19 to 23 years, sex: 11 females, 7 males) were recruited through an undergraduate psychology course and through personal contacts. Participants were from predominantly white, middle-class families. These ages were chosen based on previous research on children's understanding of biological change (Herrmann et al., 2013; Rosengren et al., 1991).

We excluded children who showed a response bias ("yes" to every question) (n = 4), children who did not complete a large portion of the task (n = 3), children for whom we were missing age data (n = 2), and one child, because English was not their first language. Two adults were excluded because of incomplete data. The final sample included 41 3- to 5-year-olds, 40 6- to 8-year-olds, 29 9- to 11-year-olds, and 15 adults.

Materials

Children were presented with two different picture sets. Stimuli were obtained from a range of animal books and Internet websites (e.g., Google Images). A number of the unfamiliar items were obtained from a book on extinct species. Familiarity and unfamiliarity were confirmed by pre-testing with an additional group of young adults. Pictures were scanned and presented as slides in a PowerPoint presentation on a laptop computer.

Each set was comprised of 64 pairs of pictures pictures. Each pair had one juvenile organism and one adult. In each image pair, the base animal was depicted on the left side of the screen and the target animal on the right side of the screen. In Set 1, the base image was a juvenile member of the species and the target was an adult member of the same species. In Set 2, the base image was an adult member of the species and the target was a juvenile member of the same species (see Figure 1). In each pair, the juvenile was depicted as smaller in size than the adult, based on previous research on children's understanding of growth (Rosengren et al., 1991).

In each set, half of the pairs contained familiar animals and half unfamiliar animals. Within the 32 familiar and 32 unfamiliar pictures per set, half of the items contained species that undergo normal growth over their lifespan (i.e., non-metamorphosis) and the other half contained species that undergo metamorphosis (for examples see Figure 2).

For each animal in the sets there were four pairs of images that represented the models of growth (see Figure 2). Pairing 1 (i.e., identical growth) consisted of mirrored larger (Set 1) or smaller (Set 2) versions of the base item. Pairing 2 (i.e., natiralistic growth) consisted of a juvenile offspring and an adult version. Pairing 3 (i.e., dramatic change) consisted of animal pairs that underwent a relatively large change in their appearance from juvenile to adult (i.e., akin to metamorphosis). Pairing 4 (i.e., species change) consisted of pictures of biologically distinct but thematically linked species (e.g., a cat and a dog). For the non-metamorphosis organisms such as mammals, the correct/possible juvenile-adult pair was presented in Pairing 2. For the metamorphosis organisms such as tadpoles, the correct/possible juvenile-adult pair was presented in Pairing 3. Examples were drawn from a wide range of animals including mammals, birds, insects, reptiles, and fish. A complete listing of the stimuli is available from the authors upon request. There were four exemplars of each type of the four pairings to represent the different category combinations (i.e. familiar & natiralistic growth, familiar & metamorphosis, unfamiliar & natiralistic growth, and familiar & metamorphosis, see Figure 2). This forced-choice questions enabled us to collect a sufficient amount of data to explore whether there are consistent patterns both within and across children. By manipulating the possible choices provided and collecting a greater number of trials than other methods enables us to do with young children, we are able to more closely examine whether the participants data fit particular patterns.

Procedure

Children were interviewed individually in a quiet location of the school, home, or in a university laboratory designed to resemble a living room. Children were briefly told the purpose of the study and then were shown the different picture sets on a laptop computer controlled by the experimenter. For the two younger groups, the first two picture sets were presented on two different days, less than one week apart. For older children, the picture sets were presented in a single session. Each of these sets used a semi-random presentation order to ensure that similar pairings did not occur one after another and that each presentation order began with two familiar items. The juvenile to adult set (Set 1) was always presented first.

During Set 1, the experimenter pointed to the juvenile item and said, “This animal looks like this now” and then pointed to the adult item and asked, “Do you think it could grow to look like this?” For Set 2, the experimenter pointed to the adult item and said, “This is an adult” and then asked, “Do you think this adult could have a baby that looked like this?” while pointing to the juvenile. This wording was based on previous work by Rosengren et al (1991). The presentation of the two sets took approximately 20 minutes each. Children’s responses were coded as yes (i.e., endorsement that the juvenile animal could grow into the adult form, or endorsement that the adult could have an offspring like the one displayed) or no (i.e., rejection of adult-juvenile pair). In effect, the endorsement is an acknowledgement that the two animals (adult/juvenile) are related or members of the same species.

Results

To examine participants' endorsement of particular types of growth as a function of age, familiarity, and metamorphosis, we conducted a 4 (age: 3–5, 6–8, 9–11, adults) by 2 (familiarity: familiar, unfamiliar) by 2 (metamorphosis: non-metamorphosis, metamorphosis) repeated measures analysis of variance in which the last two factors were within-subjects. We ran a separate ANOVA for each of the different types of change. We use the proportion of endorsements for each type of change as the dependent variable. Additional analyses were run to examine whether question type (juvenile to adult, adult to juvenile) and gender (male, female) influenced the results. No effects of these factors were obtained, so these factors were not included in any of the other analyses.

Identical growth

As a reminder, identical growth is not the biologically "correct" type of growth for any organism. We believe this type of growth represents a default essentialist bias of featural stability. As hypothesized, choosing identical growth decreases as a function of age ($F(3, 121) = 8.91$, $p < .001$, $\eta_p^2 = .181$). Bonferroni comparisons of age group revealed that 3–5 year-olds ($M = .94$, $SE = .04$) and 6–8 year-olds ($M = .92$, $SE = .04$) endorsed identical growth more than 9–11 year-olds ($M = .73$, $SE = .04$, $p < .001$) and adults ($M = .65$, $SE = .05$, p*'s* $< .005$). By age 9, children appear to understand that juveniles and adults of the same species are not necessarily identical and thus they appear to be less influenced by a bias to assume featural stability over the life span (see Figure 3).

There was a main effect of familiarity ($F(1, 121) = 24.16$, $p < .001$, $\eta_p^2 = .166$). This effect was moderated by an interaction with age ($F(1, 121) = 8.26$, $p < .001$, $\eta_p^2 = .170$). There was no significant difference for 3–5 year-olds between familiar ($M = .94$, $SE = .04$) and unfamiliar organisms ($M = .92$, $SE = .03$), or for 6–8 year-olds for familiar ($M = .90$, $SE = .04$) and unfamiliar organisms ($M = .94$, $SE = .03$). These groups were close to ceiling for their endorsement patterns. Consistent with our predictions, endorsement of the identical growth remained higher for unfamiliar organisms for 9–11 year-olds ($M = .79$, $SE = .04$) and adults ($M = .76$, $SE = .05$) than familiar organisms ($M_{9\text{–}11} = .63$, $SE_{9\text{–}11} = .05$, $p < .05$; $M_{adult} = .64$, $SE_{adult} = .07$, $p < .05$). There was also a main effect of metamorphosis with the proportion of endorsement of being higher for non-metamorphosis animals ($M = .85$, $SE = .02$) than metamorphosis animals ($M = .78$, $SE = .02$) ($F(1, 121) = 39.17$, $p < .001$, $\eta_p^2 = .245$). This was further moderated by a interaction with familiarity ($F(1, 121) = 5.67$, $p < .05$, $\eta_p^2 = .045$). The difference between the proportion of endorsement of non-metamorphosis and metamorphosis is larger for familiar than unfamiliar animals. There were no additional interactions (Metamorphosis by age: $F(3, 121) = 1.54$, $p > .05$; three-way interaction: $F(3, 121) = .83$, $p > .05$).

Taken together, these results indicate that while there are age-related changes in children's understanding that adults and offspring may differ from one another, the familiarity of the organism moderates whether individuals respond on a basis of featural stability. It should be noted, however, that identical growth was not completely discarded by the older participants, even though it was not the "correct" choice, as they endorsed these stimuli pairs roughly

50% of the time (see Figure 3). This, however, is still lower that the percentage of endorsed identical growth pairs found in children.

Naturalistic Growth

In the case of the naturalistic growth change pattern, we argue that in choosing this type of growth for non-metamorphosis organisms, which is the biologically "correct" choice, participants are shifting away from a bias for featural stability, while endorsing innate potential and immutability. There was a main effect of familiarity, with the proportion of endorsements of naturalistic growth being higher for familiar animals ($M = .63$, $SE = .02$) than unfamiliar animals ($M = .57$, $SE = .02$) ($F(1, 121) = 9.80$, $p < .01$, $\eta_p^2 = .075$). The proportion of endorsement was also higher for non-metamorphosis animals ($M = .76$, $SE = .02$) than metamorphosis animals ($M = .44$, $SE = .02$) ($F(1, 121) = 473.74$, $p < .001$, $\eta_p^2 = .797$). There was no effect of age ($F(3, 121) = 0.88$, $p > .05$), but there were age by familiarity ($F(3, 121) = 2.92$, $p < .05$, $\eta_p^2 = .067$), age by metamorphosis ($F(3, 121) = 11.39$, $p < .001$, $\eta_p^2 = .22$), and familiarity by metamorphosis ($F(1, 121) = 51.27$, $p < .001$, $\eta_p^2 = .298$) two-way interactions.

Additionally, we found the hypothesized interaction between age, type of change, and familiarity ($F(3, 121) = 12.25$, $p < .001$, $\eta_p^2 = .233$). For familiar organisms that do not undergo metamorphosis, there was no significant difference between 3–5 year-olds ($M = .74$, $SE = .03$) and 6–8 year-olds ($M = .78$, $SE = .03$), or between 9–11 year-olds ($M = .90$, $SE = .03$) and adults ($M = .95$, $SE = .04$) on the endorsement of naturalistic growth (see Figure 4). Results indicate that the mean endorsement for the two younger groups were significantly lower than that of the two older groups (p*'s* $< .05$). For familiar organisms that undergo metamorphosis, however, the pattern differed. 3–5 year olds ($M = .53$, $SE = .04$) endorsed naturalistic growth more that 6–8 year olds ($M = .40$, $SE = .04$), which in turned endorse it more than 9–11 year-olds ($M = .26$, $SE = .05$) (p*'s* $< .05$). Adults endorsed naturalistic growth for familiar organisms that undergo metamorphosis ($M = .44$, $SE = .07$) more that 6–8 and 9–11 year-olds but less than 3–5 year olds (p*'s* $< .05$).

We also predicted a similar trend for unfamiliar stimuli, which was not supported. Mean differences between 3–5 year-olds ($M = .62$, $SE = .03$), 6–8 year-olds ($M = .64$, $SE = .03$), 9–11 year-olds ($M = .67$, $SE = .04$) for organisms that do not undergo metamorphosis did not reach significance. However, adults ($M = .77$, $SE = .06$) endorsed a higher proportion of the naturalistic growth items than all the child groups (p*'s* $< .05$). For unfamiliar organisms that undergo metamorphosis, only 3–5 year-olds ($M = .41$, $SE = .04$) differed from 9–11 year-olds ($M = .52$, $SE = .05$). Our results indicate that endorsement of naturalistic growth as a mechanism of change increased as a function of age and appears to be driven by gains in knowledge of biological categories as reflected in differences between the familiar and unfamiliar organisms.

Dramatic Change

We hypothesized that organisms that undergo metamorphosis would elicit dramatic change as the preferred type of growth, and that this pattern would increase with age. The hypothesized age effect did not reach significance ($F(3, 121) = 2.66$, $p = .051$), but we found the hypothesized metamorphosis main effect ($F(1, 121) = 82.82$, $p < .001$, $\eta_p^2 = .406$) and metamorphosis by age interaction ($F(3, 121) = 13.68$, $p < .001$, $\eta_p^2 = .253$). Post-hoc comparisons revealed that 3–5 year-olds ($M = .43$, $SE = .03$), endorse dramatic growth significantly less often than 6–8 year-olds ($M = .59$, $SE = .03$), 9–11 year-olds ($M = .64$, $SE = .03$) and adults ($M = .65$, $SE = .04$) for metamorphosis items (p's< .05; see Figure 5). There ware no age differences for non-metamorphosis items. A significant three-way interaction shows that the magnitude of this effect was much greater for familiar rather than unfamiliar items ($F(3, 121) = 10.14$, $p < .001$, $\eta_p^2 = .201$) (see Figure 5). This result suggests that an understanding of dramatic change appears to develop around 6 to 8 years of age and to be linked to familiarity.

There was also a main effect of familiarity ($F(1, 121) = 82.44$, $p < .001$, $\eta_p^2 = .405$), and as predicted it was moderated by whether the organism undergoes metamorphosis during its lifespan ($F(1, 121) = 355.91$, $p < .001$, $\eta_p^2 = .746$). When restricted to metamorphosis organisms, familiar items ($M = .86$, $SE = .02$) were endorsed more often than unfamiliar ones ($M = .30$, $SE = .02$). However, for non-metamorphosis organisms, familiar items ($M = .32$, $SE = .03$) were endorsed less than unfamiliar ones ($M = .47$, $SE = .02$, $p < .05$) (see Figure 5). It was unexpected that participants endorsed metamorphosis more for unfamiliar non-metamorphosis items than for unfamiliar metamorphosis items. Because the organisms were unfamiliar, participants should have had no idea which of the organisms underwent this change. There was no familiarity by age interaction ($F(3, 121) = 0.56$ $p > .05$). When looking at stimuli that ought to undergo metamorphosis (e.g., caterpillars and tadpoles), participants were more likely to endorse the dramatic change pattern for familiar organisms than unfamiliar ones. When restricted to non-metamorphosis stimuli, participants were able to correctly reject the dramatic change pattern, although to a greater extent for familiar items.

Individual Differences

In addition to the mean analyses, we examined individual differences using binomial probability theory to determine criteria for assigning participants to a particular pattern ($p < .05$) (for example, see Gelman, 2003, p. 33) using the four distinct patterns of change: identical, natiralistic, dramatic, and species change. For this analysis, we included only those participants whose responses within each change pattern were binomially significant. Note that each pattern of change was tested using 32 stimuli pairs. Within each pattern, 16 stimuli represent familiar organisms and 16 represent unfamiliar organisms. While identical and speciation had 32 binomial trials, we chose to restrict our analysis of natiralistic growth and dramatic change to biologically correct choices. For this reason, the total number of items for natiralistic growth and dramatic change is 16. We also broke the categories down by familiarity, yielding only 8 items for the binomial analysis of natiralistic growth and metamorphosis items. For this reason, to be binomially significant we used a cutoff of 22 out of 32 for the identical and species change overall, or 12 out of 16 for familiarity effects. Additionally, cutoffs of 12 out of 16 were used for the natiralistic growth and dramatic change, and 7 out of 8 for familiarity effects ($p < 05$). Individuals could be classified as holding more than one of these patterns.

This analysis revealed striking effects of age and item familiarity on the patterns of change held by participants (see Figure 6). For the familiar organisms, depicted in the top half of Figure 6, each pattern of change shows a unique trend based on age. The number of participants who hold an identical pattern of growth decreased with age, but does not completely disappear. This pattern was held by 32 (91%) of the youngest children, 35 (88%) of the middle children, 16 (59%) of the oldest children and 7 (58%) adults. The fact that the identical growth pattern was still present for half of the adults aligns with the mean results, and supports our contention that an identical pattern of change is a life-long bias that is related to age and familiarity, but never fully replaced. In line with our second prediction, the number of participants who hold the naturalistic growth and dramatic change patterns increased with age. The naturalistic growth pattern was held by 17 (50%) of the youngest children, 20 (50%) of the middle children, 23 (85%) of the oldest children and all of the adults. In a similar fashion, the dramatic change pattern was held by 8 (23%) of the youngest children, 29 (74%) of the middle children, 24 (89%) of the oldest children and 12 (92%) of the adults. No participants at any age group exhibited a species pattern of change for familiar items.

For the unfamiliar items, the trends differ. In this analysis, we found that the identical growth pattern was higher for older children and adults than younger children, revealing the tendency to default to this pattern of change when presented with an unfamiliar living kind. Thirty-three (94%) of the youngest children, 39 (98%) of the middle children, 21 (78%) of the oldest children and 10 (77%) of the adults hold an identical pattern of growth for these items. Moreover, the number of participants who hold naturalistic growth and dramatic change patterns is low across all age groups, revealing the importance of familiarity to participants' endorsement of these change patterns. Specifically, three (9%) of the youngest children, 10 (25%) of the middle children, 5 (19%) of the oldest children and 5 (42%) of the adults apply the naturalistic growth pattern to unfamiliar organisms. One (3%) of the youngest children, 1 (3%) of the middle children, 1 (4%) of the oldest children and none of the adults hold the metamorphosis pattern, revealing that is practically non-existent for these unfamiliar items. No participant exhibited speciation as a growth pattern for unfamiliar items.

Discussion

In the present study, we investigated the developmental trajectories in children and adults' endorsement of four patterns of biological change. As can be seen in Table 1, we proposed that the endorsement of each pattern was linked to different components of essentialism reasonin. Our data suggest that innate potential, and immutability of category identity, two components of essentialist reasoning about living kinds, become stronger over development and interact with participants' level of familiarity with the organisms. Furthermore, we found strong evidence that a featural stability bias is present throughout development, particularly when individuals' lack specific category knowledge. We propose that this may an integral part of a folk biology, one that emerges early in development and remains a default mode of reasoning into adulthood, influencing how individuals reason about biological change.

Specifically, we found support for our four hypotheses. First, the change pattern of identical growth was commonly endorsed by 3- to 5-year-old children for both familiar and unfamiliar items, and for all participants when reasoning about unfamiliar items. We argue this is due to a featural stability bias, an assumption that physical features remain stable across the life cycle. Second, the endorsement of the pattern of naturalistic growth increased with age, particularly for familiar items. We argue this reflects an increase in innate potentiality as children think that organisms will change in predictable ways. Third, endorsement of metamorphosis for organisms that undergo this type of change increased with age (e.g., insects). This reflects an even greater increase in innate potentiality as children endorsed that a specific larva will turn into a specific adult. Additionally, we argue that endorsing metamorphosis also reflects immutability thinking as children should realize that despite the superficial changes it is still the same animal. Finally, endorsement of species change pattern was uncommon for all ages and items, and none of the participants consistently endorsed this type of change. The rejection of this model is an important control, indicating that even the preschoolers were discriminating amongst different change patterns.

Familiarity and Patterns of Change

The results of this study suggest as well as the age of the participant, familiarity with particular biological kinds influenced the patterns of changes that an individual would endorse. In our study, the two change patterns of naturalistic growth and metamorphosis were endorsed more strongly for familiar than unfamiliar items. Notably, neither older children nor adults generalized these principles by applying these two change patterns to unfamiliar organisms. This suggests that metamorphosis may be counterintuitive and that it may be learned on a case-by-case basis. That is, even if participants know that caterpillars turn in to butterflies, this knowledge of a particular pattern of change is not generalized to unfamiliar organisms, not even other insects. This is interesting given that almost all insects undergo metamorphosis.

Our results are consistent with findings reported by Herrmann, French, DeHart, and Rosengren (2013) who have shown in an intervention study that direct experience with a species undergoing metamorphosis increases children's acceptance of metamorphosis, but only for that species, However, Menendez, Rosengren and Alibali (2017) have shown that school-aged children can generalize a dramatic change pattern to other insects after a receiving a lesson on the metamorphosis of a ladybug.

The results obtained for unfamiliar items suggest an early emerging bias to assume featural stability over the lifespan. This is shown through endorsement of the identical growth pattern, in which there is an increase in size, only. We suggest that featural stability appears to be a default bias when reasoning about life cycle changes for young children and adults faced with unfamiliar organisms.

The perseverance of the belief on featural stability is in line with recent research on intuitive theories in other domains. Shtulman and Harrington (2016) found that when individuals, even professional scientists, were asked to endorse statements they take longer to endorse ones that challenge commonplace intuitions about the world. These authors and others claim that our intuitive theories are not completely replaced with increasing knowledge and experience, but rather are suppressed by our scientific theories (Coley, Arenson, Xu, & Tanner, 2017; Evans, 2001; Evans & Lane, 2011; Shtulman & Valcarcel, 2012). The endorsement of identical change for unfamiliar animals is analogous to the findings reported by Shtulman and colleagues, where individuals continue to endorse intuitive forms of change, such as identical growth, even though they likely know about other, biologically correct forms of change, such as naturalistic growth and metamorphosis.

As described earlier, we hypothesize that each of the patterns of change examined in the current study are constrained by specific components of psychological essentialism. The featural stability bias appears to emerge early as should by 3- to 5-year-olds endorsing predominantly the identical growth pattern. And so featural stability appears to be the default when reasoning about change over time. As mentioned in the introduction, the featural stability bias can be conceptualized as an extreme version of the immutability constraint. For this reason, we believe, featural stability may be considered a initial component of psychological essentialism. Our growth models also assess more mature components such as innate potential and immutability of identity (e.g., naturalistic growth and metamorphosis). These components are modified over time and appear to be tied to knowledge of the biological category. These more mature manifestations of essentialist reasoning appear with increasing age and knowledge, as reflected in age related changes in the endorsement of both naturalistic growth and metamorphosis. However, for unfamiliar organisms, featural stability remains as a default constraint. We suggest that innate potential and immutability may operate at a more reflective and abstract level of reasoning that is influenced by age and increased knowledge in a domain (Evans & Lane, 2011; Evans & Rosengren, in press).

Essentialist reasoning enables even young children to go beyond surface similarity when generalizing category membership and traits. Studies demonstrating this capacity focus on the the role of labels in highlighting category essences (Gelman & Coley, 1990; Gelman & Markman, 1987; Waxman, 1998). These findings would appear to challenge the thesis advanced in this paper, that featural stability is the first form of essentialism to emerge. We suggest that language may move children from an automatic processing to a reflective abstract level of reasoning. At the same time, the use of generics (e.g., all robins have red breasts) may serve to highlight the homogeneity of category membership and thus reinforce featural stability. This is a matter for further empirical investigation.

Our way of thinking about essentialism resembles that of Cimpian and Salomon's (2014) inherence heuristic. They argue that when individuals seek explanations about a phenomenon a mental shotgun activates relevant information related to the topic. The mental shotgun retrieves easily accessible facts (likely part of an intuitive theory) as fast as it can. For unfamiliar species, the mental shotgun gathers the information that was easiest to access, given the featural stability bias, this information likely resembled an identical model of change. We argue that one of the reasons why individuals adopted a naturalistic and metamorphosis pattern of growth more often for familiar species is because the information about the correct type of change was easily accessed given their previous experience with the species.

It should be noted that the 6- to 8-year olds in this study were more likely to endorse the metamorphosis pattern of change than the naturalistic growth one. This age is one where students are exposed to information about metamorphosis in school. Perhaps, the counterintuitive nature of metamorphosis life cycle changes is so striking that it engenders acceptance of biological change more broadly (see Evans, 2013).

We believe that an essentialist perspective with the addition of a focus on featural stability provides a more compelling account of our results compared to a number of potentially plausible alternatives. One alternative explanation that has been used to describe the development of folk-biology articulated by Carey (1985, 1996) suggests that children's judgments about biological organisms are based on their similarity to humans. This account, however, cannot explain the current results because humans undergo naturalistic growth. If participants were reasoning based on their knowledge of humans, then naturalistic, and not identical growth should have been the default judgment. Other similarity-based approaches also do not do an adequate job of explaining the pattern of results found in this paper. In particular, prototype-based theories (Rosch, 1973) are not able to explain the effect of familiarity that we found. These accounts suggest that individuals are more likely to generalize the features of a prototypical, rather than an atypical, category member. Given that the familiar animals in this study are more likely to be closer to the prototype than the unfamiliar animal, prototype-based theories would predict that participants would extend their knowledge about growth in these species to the unfamiliar species. Our results both at the group and the individual level do not reflect this pattern given that older children and adults did not endorse the same patterns of change the familiar and the unfamiliar species.

One other account that could lead to a feature stability bias is a statistical learning model. Statistical learning has been proposed as a domain-general mechanism that underlies perceptual learning in humans and several animal species (Saffran, Aslin, & Newport, 1996; Saffran, Hauser, Seibel, Kapfhamer, Tsao, & Cushman, 2008). Statistical learning also seems to support inferences in opaque domains such as social norms (Riggs, under review). Given that for many organisms' growth occurs over a long period and is very gradual (e.g., a person normally does not change much from one day to the next), it is unlikely that individuals will observe changes occurring over the lifespan. Rather, repeated observations of the same organism over a short time window will imply that organisms do not change (i.e., featural stability). This account could support why both children and adults have a bias for featural stability for unfamiliar organisms. As children gather more information, they learn to connect the juvenile and adult forms of species typical in their environment, altering their expectations of growth for these specific species. However, when facing an unfamiliar species, individuals might rely on the most prominent pattern they have seen, which is identical change.

It has been proposed that aspects of essentialist reasoning influences both children's and adults' difficulty with biological concepts related to evolutionary change (Evans 2000, 2001; Evans, Rosengren, Lane & Price, 2012; Coley & Muratore, 2012; Gelman & Rhodes, 2012; Shtulman, & Calabi, 2012). Essentialist reasoning –particularly the proposed featural stability bias- may support that idea that members of species are highly similar. The recognition that members of species exhibit variability is a key component of understanding natural selection (Evans et al., 2010; Shtulman & Calbri, 2012, 2013, Shtulman & Schultz, 2008). Emmons and Kelemen (2015) suggest that certain contexts can help individuals consider greater levels of within species variation. We suggest that learning about life cycle changes, especially dramatic changes such as metamorphosis, might facilitate a greater understanding of within species variability (see also Evans, 2000). We hypothesize that recognition that individuals may vary considerably over the life span might enable individuals to become aware to a greater extent of within species variability, opening the door to more sophisticated reasoning about how variability might be involved in adaption to changing environments. This is an issue for future investigations.

To date, we are the first to suggest that different forms of essentialism may emerge at different ages and may operate at different levels of abstraction. Furthermore, some biases such as featural stability appear to operate independently of gains in knowledge and can be elicited when reasoning about unfamiliar categories. This accords with other accounts that suggest essentialist reasoning may not be uniform across development (Gelman & Legare, 2007; Diesendruck & Gelman,1999; Poling & Evans, 2002).

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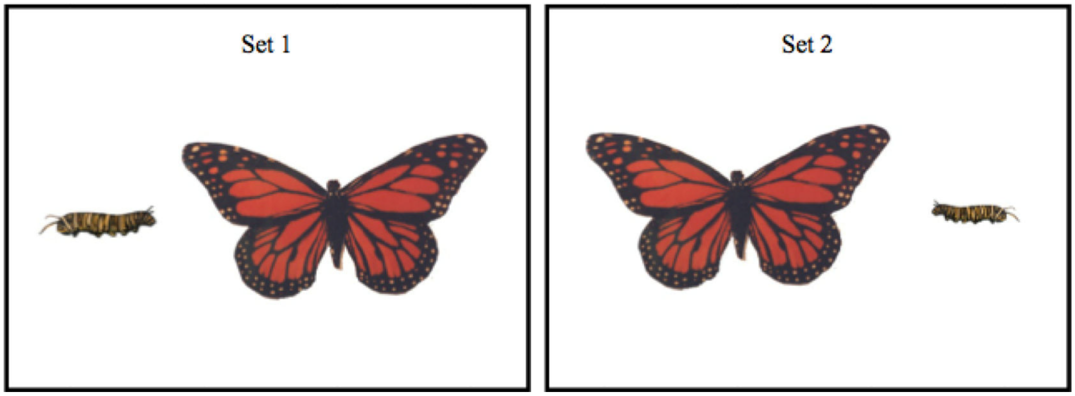

Figure 1.
Sample stimuli from Set 1 and Set 2.

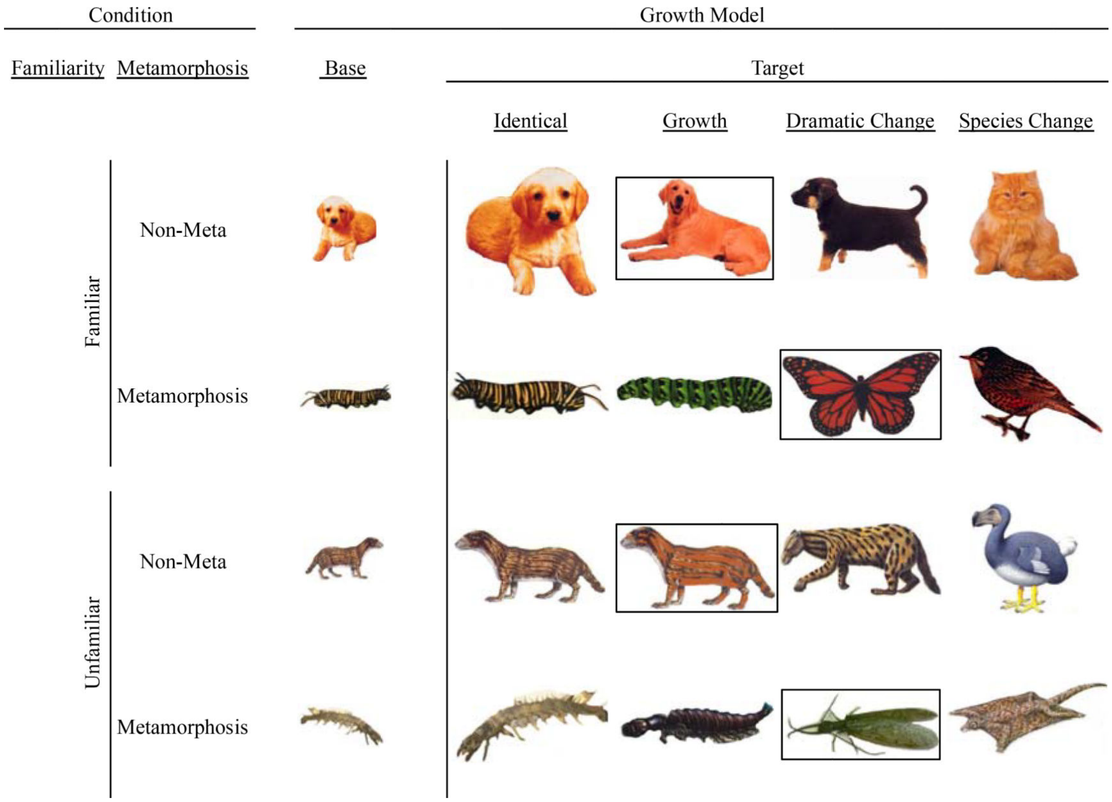

Figure 2.

Examples of organism pairs by change pattern and organism condition. This figure illustrates one of the 8 organism pairs for each of the 4 conditions and 4 growth models. Targets with a black border represent a correct target for that particular growth model. Thus, the identical growth model and the species change model are never biologically correct targets for both metamorphosis and non-metamorphosis organism types.

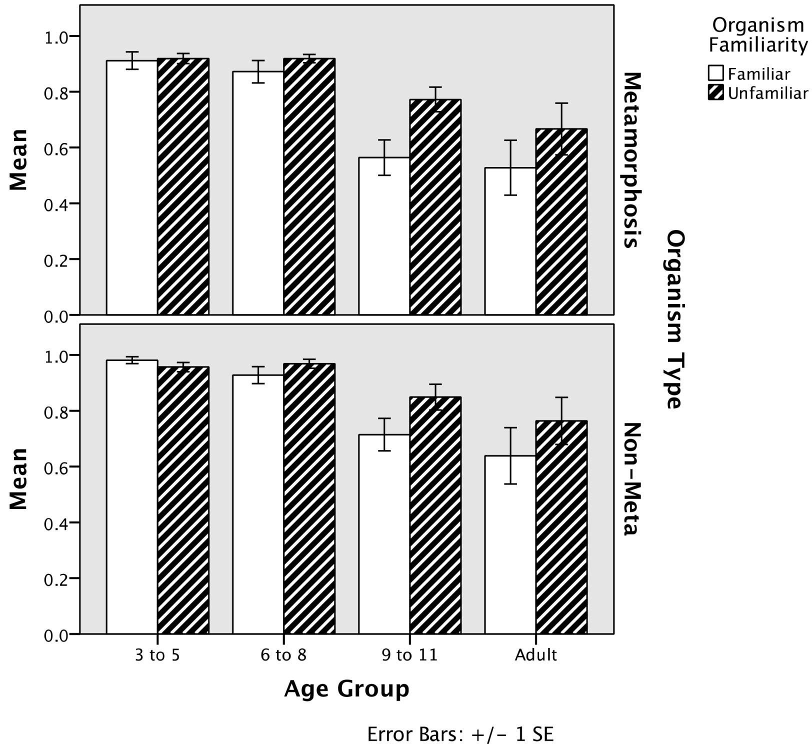

Figure 3.
Percent of participants endorsing identical growth change pattern by age group, organism type, and organism familiarity.

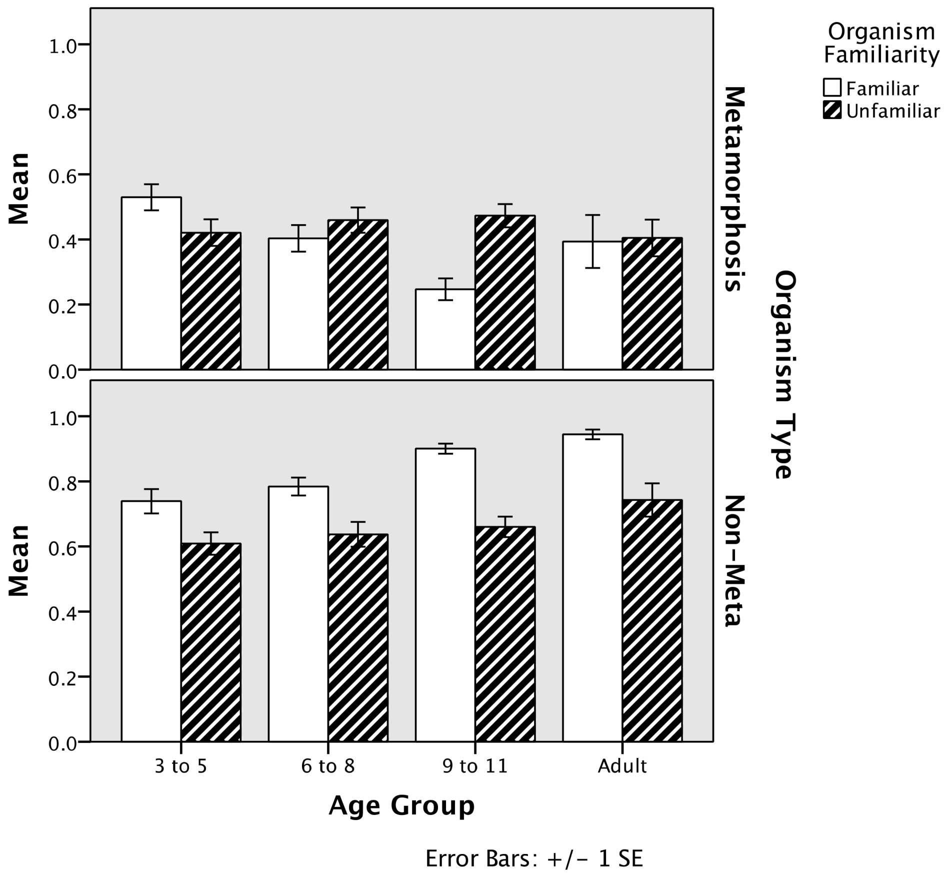

Figure 4.
Percent of subjects endorsing the naturalistic growth pattern by age group, organism type, and organism familiarity.

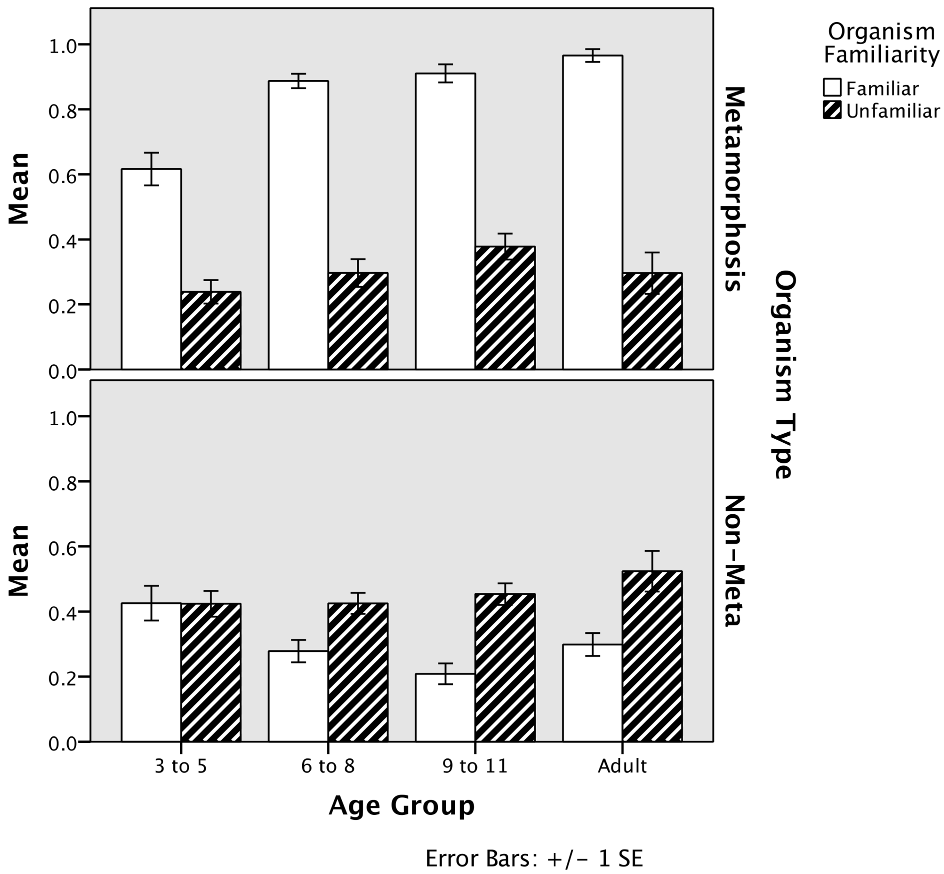

Figure 5.
Percent of subjects endorsing the dramatic change pattern by age group, organism type, and organism familiarity.

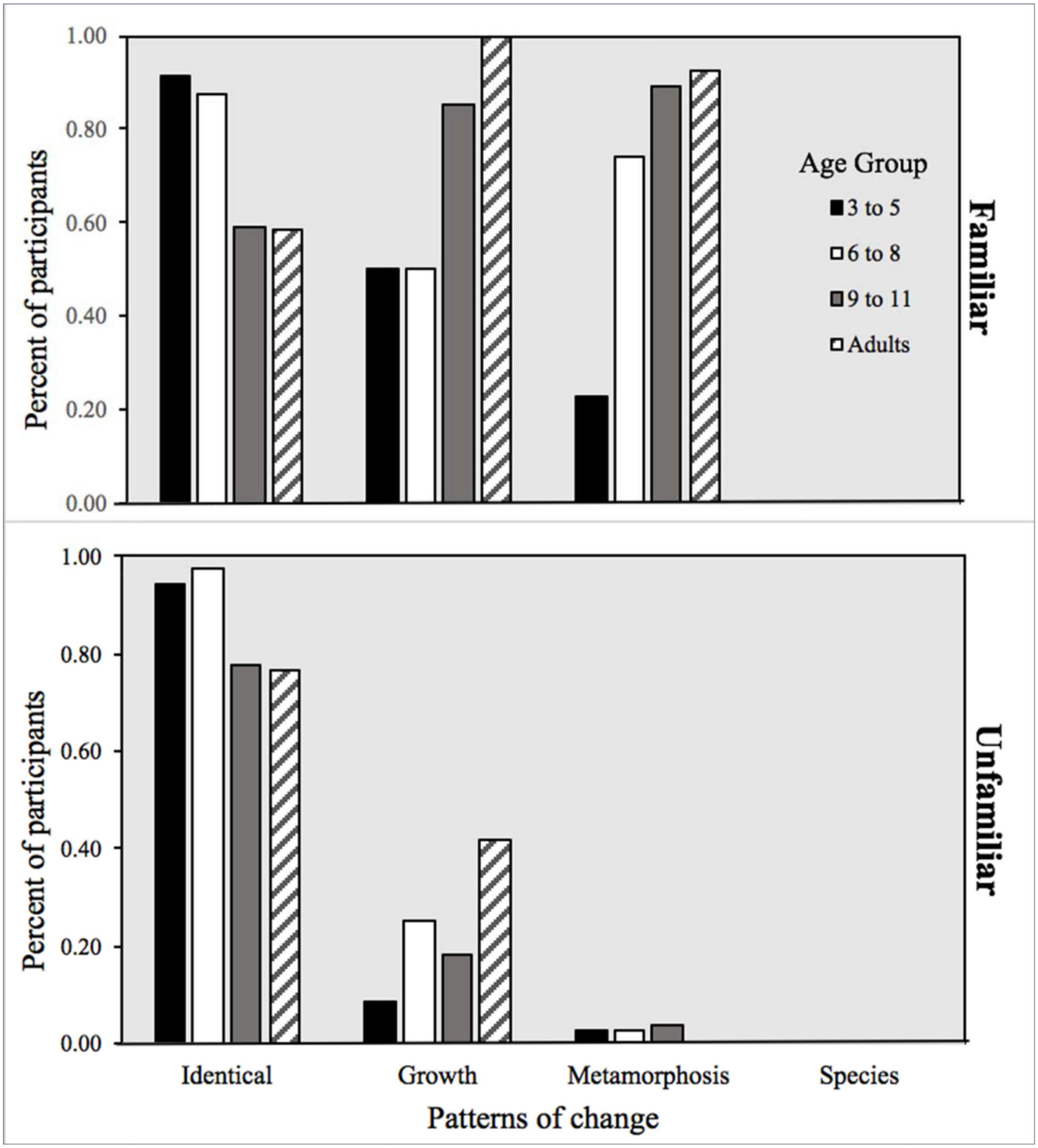

Figure 6.

Percent of subjects endorsing particular change patterns based on binomial pattern analyses. This figure demonstrates the change patterns held by particular age groups by organism familiarity. None of the participants endorsed the speciation pattern of change.

Table 1.

Patterns of change mapped to the different component of essentialism

Pattern of change	Component of essentialism
Identical	Featural stability bias
Naturalistic	Innate potential
Dramatic	Immutability, Innate potential
Species	None