CHILDREN'S AND ADULTS' KNOWLEDGE OF SPECIES-GENERAL AND SPECIES-SPECIFIC CHANGES DURING PHYSICAL GROWTH AND DEVELOPMENT

By

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In memory of my beloved father S. L. Narasimham

and

To my beloved mother Shyamala Narasimham

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Living things grow. From the splitting of cells in the tiniest embryo to the phenomenal growth strides of the blue whale calf, biological growth is at once pervasive and inevitable. Even from a young age, children are fascinated by the apparent transformations that accompany development in animals. Leaf through any issue of the teachers' trade journal *Science and Children*, and you will notice that growth in different organisms is a popular topic among preschoolers and older children. Or consider this report from a preschool teacher in New York:

> "…As the children observe all the natural changes that are occurring around them, they in turn document the growth and changes that have happened to them in their lives. They bring in photographs of themselves as infants and toddlers, which they use to write stories about their "younger years." Parents bring in babies to the classroom: children observe and play with them…" (Foote, Stafford, & Cuffaro, 1992, p. 65).

A reasonable question then, is what do children know about growth-related changes in the organisms sharing their worlds. This concern is emphasized in the United States, where the National Science Education Standards (National Research Council, 1996), and the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) prescribe knowledge of familiar organisms and their life-cycle changes as part of the curriculum objectives for the Kindergarten classes and beyond.

It follows then, that concepts about developmental changes ought to be a topic of interest to researchers in many fields including anthropology, developmental psychology, and education. Indeed, research in the past few decades has uncovered much about children's biological understanding (e.g., Carey, 1985; Gelman, 1988; Hatano & Inagaki, 1994; Keil, 1989; Piaget, 1929; Siegal & Peterson, 1999). And yet, only a handful of studies have examined what children understand about growth in human and familiar types of non-human animals (e.g. Langford, 1975; Nash, 1973; Rosengren, Gelman, Kalish, & McCormick, 1991; Tamir, Gal-Chappin, & Nussnovitz, 1981).

These studies reveal several interesting findings: First, most preschoolers understand[1] that growth involves an *increase in size*, and happens only in natural kinds such as animals and plants, but not artifacts (e.g., Langford, 1975; Rosengren et al., 1991). Second, preschoolers know[1] that human babies undergo changes in *the relative sizes of the head vs. body* (Nash, 1975), but we don't know if this knowledge extends to other animals. This is important, because we do not know whether young children's knowledge that heads become smaller with age in relation to the trunk is tied specifically to their concepts of "human babies", or instead whether it reflects implicit knowledge of a more general rule covering a wider range of animal species. Third, younger preschoolers have difficulty accepting transformations resulting through natural processes such as metamorphosis where the adult form is perceptually dissimilar to the younger form (Rosengren et al., 1991). Fourth, most preschoolers have difficulty accepting that growth changes the characteristics of particular individuals who they may know over time. For example, Bales and Sera (1995) found that preschoolers do not understand that two pictures, one of a girl and another of a woman, could be of the same person (Bales & Sera, 1995). Finally, even grade-school children seem to have no clear concepts about growth in plants or animals (Shepardson, 1997; Smith & Wesley, 2000; Tamir et al., 1981).

Taken together these studies reveal a *fragmented* picture:

[1] I use the words understand/understanding and know/knowledge to mean children's *usage* of a particular concept or principle to determine growth, for e.g., a rule based on size changes. The present study attempts to describe what principles children (and adults) use in determining growth, not discuss whether these principles are appropriate.

i. By the age of 3 or 4-years, most children probably understand that growth involves size changes in forms that look similar across ages, an understanding that becomes more sophisticated with age. Children also have some understanding about proportional changes, but this is limited to the human species.

ii. Most young children probably understand little about changes that result in perceptually *dissimilar* forms.

iii. Most young children probably do not understand that across the life-span, the individual's identity remains the same.

Many questions are unresolved by the existing research. Consider these three: First, given that young children appear to understand that size increases with age, do they also understand that size increases globally for some species [e.g. reptiles, see details below] whereas for other species body size increases at a faster rate than head size? We need to re-examine what young children understand about growth in different organisms.

Second, how do these concepts change with age—i.e., what are some of the key things that older children and adults understand about growth in different organisms that younger children do not understand? For example, do older and younger children share a common understanding that all animals grow in size as they mature, or do younger children have a narrower concept that is limited to animals with which they are familiar? As another example, do older and younger children share a common understanding that all mammals change in body proportions with age, or is the younger children's concept more limited to human infants and other highly familiar species?

And finally, some children will likely know more than other children about biological growth. But what is not known is the degree to which such individual differences within an age grouping might reflect highly general differences in knowledge on the one hand or differences in specific experiences with different animal species on the other hand. Such differences might vary with children's personal enthusiasms [e.g. deep interest in animals], family differences [for example, whether children live with pets or on farms or with parents who are animal biologists], and with cultural grouping [some cultures differ from others in exposure to animal life; cultures differ in folk biological beliefs about animal life, growth, and death].

In this study, I propose to examine the first two questions: the first in order to find out about young children's concepts and the generality of their concepts across different species of familiar mammals and reptiles, and the second, to find out about changes in the concepts and generality of concepts in older children and adults. First, I present a brief synopsis of scientific concepts about growth and folkbiological understanding of growth. Then I examine the literature on children's biological concepts and findings about children's understanding of growth and external transformations. Finally, I will present the rationale for study and describe the methods I used.

Biological growth: What do people know?

A logical beginning to answer this question is to review existing information from scientific and folkbiological sources. The first provides us some grounding about exactly what has been known and the second, an idea about what most adults in a particular culture know. In this section, I provide a synopsis of the scientific knowledge about growth patterns in different organisms that are potentially relevant to the current study, followed by folk knowledge about these patterns.

Growth: The scientific view

Developmental trajectories in nature are intricate and varied, but a ubiquitous pattern is that members of a genus follow similar stages during growth, and members of different genera sometimes follow different patterns. Classificatory systems are helpful in inferring these patterns. Aristotle (384-322 B.C.E.) was the earliest known philosopher to introduce a taxonomic system to organize animals and plants based on their morphology. Current classification systems have developed from Linnaeus' (1753) original work. Modern classification systems have many levels of hierarchical organization. These systems are taxonomic (based on structural and physiological connections between organisms), phylogenic (based on genetic connections between organisms) and are grounded on Darwin's theory of evolution (Pidwirny, 2001). Table 1 provides the hierarchical classification system for one species.

Table 1: Scientific and folkbiological taxonomic categories for a sample species

Scientific system		Folkbiological system
Kingdom	Animalia	Animals
Phylum	Chordata	Life form
Subphylum	Vertebrata	-
Class	Mammalia	Mammals
Order	Carnivora	-
Family	Canidae	Dogs
Genus	Canis	-
Species	Canis lupus familiaris	Common dog

The growth of every organism is regulated by genetics. This regulation governs not only size and shape, but also the timetable by which a given animal will develop. Even so, adequate allowance is made for individual differences in the phenotype. Within each species, further individuality comes about as the result of their unique adaptation to the environment. Almost all animals begin their life through fertilization, or the fusion of two sets of complementing chromosomes from their parents resulting in the embryo (except certain unicellular organisms). The embryo undergoes a series of changes at the cellular level including cell multiplication and differentiation, tissue and organ formation that eventually results in a new individual of the species. Growth does not stop with the formation of this new individual. Indeed, the process continues through the life of the individual, for e.g., nails re-grow throughout the life-span. In most cases however, the new individual is not a sexually mature adult at birth. The period to maturity varies with different species. In nearly all organisms the most important expression of growth is *polarity*—the basic indication of the direction in which a creature develops, for example along the radial axis such as in starfish or along a head-tail axis such as in humans. In most cases the polarity is established in the embryo, and in animals in the higher phyla (e.g., vertebrates) the polarity is along the cephalo-caudal or head-to-tail axis, i.e., bilaterally symmetric, which implies that growth is symmetric along this axis. Animals grow by increasing in size, but that is just one aspect of growth. Various parts of the body differ in the ultimate size they will reach, a difference captured by proportional changes. In nearly all vertebrates, the head-to-body proportion changes from infancy to adulthood. The head size remains more or less constant but the body continues to increase in size, reaching the optimal height and weight set by a combination of genetic and environmental factors. Also, limbs increase in length proportionally to the weight of the body.

Besides size and proportional changes, growth also involves morphological changes. Different species sometimes show different patterns of growth [Table 2 below]. Thus for mammals, these morphological changes may involve the appearance of secondary sexual characteristics, and the growth of appendages such as horns. In other species, such as birds and reptiles, the external skin/feather color may show changes. In some species, the changes are more marked as in the case of amphibious reptiles and insects. These metamorphic changes include the differentiation of the body into the thorax and abdomen, and the appearance of limbs (amphibians and insects) or wings (insects). In some cases, morphological changes also include the disappearance of juvenile features such as gills (amphibians).

Table 2: Schemata of growth-related changes in organisms belonging to major folkbiological categories

Categories / Changes	**Mammals**	**Birds**	**Reptiles**	**Fishes**	**Residual categories (insects, worms)**
Size	Increase	Increase	Increase	Increase	Variable
Proportion	Head smaller, torso larger*	Head smaller, torso larger*	No change	Head smaller, torso larger*	N/A
Morphology	Secondary sexual characters, longer hair, horns, antlers etc	Longer Wings, color changes	Skin-color changes	Skin-color changes	Marked body segmentation (worms)
Metamorphic	N/A	N/A	Absence of gills, growth of limbs (amphibians)	N/A	Segmentation of body, growth of wings (insects)

Note: From Myers (1999). *As growth progresses, head growth is proportionately lesser compared to growth of the torso or body.

Growth: Folk concepts

People's common knowledge about growth in familiar organisms is captured by their classificatory system. Long before Aristotle, Darwin or Linnaeus, people around the world were classifying living entities around them. This is never more apparent than in the category names in all languages for locally found animals and plants (see Berlin, 1992, for a review of ethnobiological classification). Several ethnobiologists have noted that folk biology follows a hierarchical organization, similar among peoples of both industrialized and subsistence cultures (Atran, 1990; Berlin, Breedlove, & Raven, 1973; Brown, 1979). In this system, living things are classified as belonging to one of two kingdoms (i.e., plants or animals). They are further subdivided into life-forms, families, genera, and species. Across cultures, the larger life forms have been distinguished into major life form groupings, but not the smaller. An obvious reason is that larger life forms are more visible, and easier to observe. Thus most people have classified vertebrates into several distinct groups such as fishes, amphibians, reptiles, birds and mammals but invertebrate forms are usually grouped into a residual category (Atran, 1990). Table 1 above provides a sample classification according to this system.

What follows from above is that people are bound to have certain expectations about the developmental patterns of organisms around them, based on some direct observation as well as inductive generalization. Most people probably have some ideas about how human infants grow and also have a more differentiated understanding of how mammals grow than how other animals grow. Indeed, studies looking at people's perceptual judgment of <u>human</u> growth (e.g., Mark, Shapiro, & Todd, 1986; Mark, Shaw, & Pittenger, 1988; Pittenger & Shaw, 1975; Pittenger & Todd, 1983) show that most people base their judgments on relative head-body proportion.

Note these findings are about people's *implicit* knowledge—knowledge that is revealed through performance on tasks like the judgment tasks discussed above, i.e., "rules" about the size and proportional changes that people use to determine growth. Explicit knowledge, on the other hand, is revealed when people are asked to verbally *state* the rules they use[2] (Schacter, 1987). People may have some implicit and explicit folk knowledge about the developmental patterns of other vertebrates such as birds, reptiles, amphibians and fishes since these are bigger, and easier to observe. Further many of these species are household pets or have been domesticated by humans. However, their knowledge about insects and worms or other invertebrates may not be very sophisticated because these animals are more difficult to observe. The changes listed in Table 2 above for the major life-forms lists some common concepts about growth-related changes in animals.

What I wish to emphasize here is that although scientific concepts about growth in different animals are readily available, there is sparse literature on folk or common conceptions about growth related changes in familiar organisms. A result is that we have no clear understanding of how children's and adults' concepts about growth differ or are similar, and how these concepts develop.

Children's understanding of growth

Most adults may know that if some entity is alive then it follows some trajectory of growth and development, although this may be an implicit inference. This leads to the next question: what do children know about growth, both implicitly (i.e., using principles to judge growth) and explicitly (i.e., stating the rules they use)? Before we can answer this question, we

[2] We do not claim if people can verbally articulate their explicit knowledge, then they cannot articulate their implicit knowledge; only that people's use of certain principles is implicit in their judgments and explicit in their statements.

need to examine what children understand about living things because biological growth is an exclusive feature of only living organisms.

Children's understanding of what is alive

A few decades ago, most researchers in the field of cognitive development thought that children are limited by their perceptions and form inconsistent ideas about things around them (Piaget & Inhelder, 1954; Vygotsky, 1930). In the earliest studies that were done, Piaget (1929) sought to understand how children come to know what is alive, and how this concept changes with age. He probed children with questions about whether specific things were alive. Very young children in his study were generally inconsistent about what they thought was alive. Older children classified anything that was active (visibly moved or performed a function, such as the sun, oven, bicycles) as alive, later only those things that moved autonomously, and around 12 years, attributed life to animals, plants and people. Piaget concluded that children progress in stages, starting from an unclear concept, to gradually defining life in terms of multiple functions like adults do (i.e., attributing life to those organisms capable of breathing, metabolism, growth, and reproduction).

Several studies have shown that children have a mature understanding of what is alive much earlier than Piaget thought. Studies that have examined the distinction between *animals and non-living things* have shown that even preschool children can distinguish animals from non living things in terms of the ability to make self-initiated movements (e.g., Bullock, 1985; Massey & Gelman, 1988), the possession of certain observable properties (e.g., has a mouth, walks etc., Gelman, Spelke, & Meck, 1983) or natural transformations over time (Rosengren et al., 1991).

However, studies that have examined the distinction between living things including plants, and non-living things have shown that children lack this knowledge before around 7-years. Richards and Siegler (1984) revealed that less than 20% of 4- and 5-year olds and 50% of 6-year olds judged both animals (including humans) and plants to be alive. Richards and Siegler (1986) found that 4-year-olds who were asked for characteristics of living things gave attributes that are true of animals but not of plants. When asked to decide whether living things from another planet were alive, children relied on properties which are true of animals (for example movement, having babies) but not living things in general (e.g., breathing). Stavy and Wax (1989) found that only 30-60% of children around 6-11 years classified plants correctly as living things. Carey's (1985) study revealed that when asked about unseen, novel properties (for e.g., "X has *golgi*, which other _____ (ENTITY NAME) has *golgi*?"), even 6-year-old children did not base their inferences on the differences between living and non-living things. For instance, when children were taught that these novel properties were present in dogs and flowers, they often over-attributed the properties to include inanimate objects.

Children's concepts about biological growth: A brief review

The studies reviewed above reveal that children have different concepts about what is alive than adults. On the face of evidence that young children consider only animals to be "alive" in many ways that adults do, we can expect children will grant growth only to animals. However, if children equate growth with becoming bigger in size, then we can expect that children will extend the concept of growth to plants and animals, though they may not understand that plants are alive.

This hypothesis is confirmed by several studies which show that young children recognize commonalities between animals and plants, when asked about specific properties such as growth. Danziger and Smith (1958) found that children between 5- and 8-years knew that animals and plants grow, and that growth involved an increase in size. Hatano, Siegler, Richards, Inagaki, Stavy and Wax (1993) showed that 5- and 6-year-old children in Israel, Japan, and the United States attributed properties such as “grow,” and “die or wither,” to animals and plants, but not to inanimate things. Stavy and Wax (1989) also reported that though most children below 11-years failed to attribute properties such as breathing, eating, or reproduction to plants, they correctly attributed the property of growth to plants; many children answered that plants grew but were not alive. Keil (1983) found that kindergartners correctly applied the predicate *grow* to both animals and plants, though they applied other predicates such as alive, sick, and starve to animals only. Inagaki and Hatano (1996) showed that even by age 4, children had grasped the commonalities between animals and plants in terms of growth.

The studies mentioned above have treated growth as one of the properties of a living thing. In these studies, typically the child was asked about a specific property (e.g., breathing) of one particular animal or plant. After the child responded, the experimenter went on to question the child about the relevance of this property to a list of living things, and/ or inanimate objects. Further, all these studies have confounded growth in plants and animals, although growth is manifested differently in these two kingdoms, with the exception of size. Most living things increase in size during growth, but the obvious similarity ends there. Table 2 above indicates that growth in animals is not merely an increase in size. Plants have similar complex patterns of growth that are distinct from animals. A discussion of growth patterns in plants is however, not of relevance of to this paper, expect to note the difference.

Children's concepts of growth in animals

The question of current interest is what children understand about growth in animals. One of the first studies to examine this question was done by Rosengren et al (1991). In their experiments, they showed children pictures of animals (e.g., dog, salamander etc.) or artifacts (e.g., clock, box). They introduced the animals as a "baby ______," and asked children whether the animal will remain the same or change and resemble either of two target pictures. One target picture showed the animal in a larger size, and another in the same size as the standard (Experiment 1) or a smaller size (Experiment 2). They used a similar procedure with artifacts (Experiment 1 only). Children predominantly selected the larger animal (indicating that baby animals will change and grow larger) but suggested that artifacts will remain the same. Rosengren et al., however did not test for children's knowledge about proportional changes or changes in external morphology.

Biological growth in animals involves species specific processes including changes in size and proportion, and morphology. Some aspects of growth involve the entire organism and can be easily perceived, unlike processes such as metabolism or digestion. But growth involves very gradual changes and this requires some understanding about the sequences of the changes taking place. Although Rosengren et al. (1991) tested this concept of sequential progress indirectly (i.e., children were asked about the change in size over time), their objective was not whether children understood that growth follows a specific direction.

In one of the earliest studies, Nash (1973) showed children between 3- and 5-years of age five pictures of human-like figures. These figures were line-drawings depicting the head, body, and limbs but no facial features or other details. The figures were similar in overall size but differed in the size of the head relative to the body. When asked to judge the ages of these figures, children relied on the relative head-body proportion. That is, most children judged figures that had a large head relative to the body as *younger* and those with a smaller head relative to the body as older. Further, children could order most of the figures by age. This study reveals that young children have some rudimentary concepts about sequential changes as well as the importance of proportional changes when it comes to judging human growth. However, Nash tested children only on one set of human-like figures. We do not know if children can extend such principles to other animals. Furthermore, we do not know if children will select proportional changes when conflicting with size changes, or other external changes such as the position of eyes in the face.

Langford (1975) investigated three-, four-, five-year-old, and older children's understanding of quantitative (e.g. size) and qualitative (e.g., appearance) changes involved in growth across the life-span. She tested children on a seriation task using pictures showing the developmental stages of a frog, butterfly, human and bird. All the pictures depicted size changes as well as correlated qualitative changes. For example, three pictures depicted tadpoles of different sizes and another three, frogs of different sizes. The children were asked to show how an animal grew by arranging four of the six pictures on a picture board. In an "easy" version, children were given only four pictures. In the "hard" version children were given all six pictures but were required to use only four. Langford found that even 4-year-olds could order the pictures correctly but younger children could only attend to either the size change or the appearance change and not both. Five-year old children could coordinate both aspects, and were consistent in their judgments across different species of animals.

In a more recent study, DeHart, Rosengren and Prostka (in preparation) presented 4-year-olds with two tasks. In one task (the “mother-baby” task), children saw pictures of the “baby” animal, and four target pictures. The targets included the appropriate adult, a blown-up picture of the baby, a baby and an adult from a related but different species. The experimenter asked the children which one of the target could be the mother of the "baby." Across different species, children chose the appropriate adult forms in species where the baby does not undergo dramatic changes (i.e., where the external appearance changes considerably). In the second task ("possible changes task"), children were shown the "baby" pictures again; this time however, their task was to say whether the baby will remain the same or can change to resemble one of two target pictures. These targets included an appropriate adult (i.e., a possible change), and an adult from a different species (i.e., an impossible change). Again, children selected the appropriate adult only on those species that did not undergo dramatic changes such as metamorphosis.

In sum, children seem to rely on perceptual similarity between the young and adult forms when judging growth, i.e., they think that animals grow in size, but for the most part resemble the younger forms. Among the first concepts to develop is the idea that size increases with growth; around 3-years they seem to know about proportional changes in human figures. Finally, children have difficulty understand that growth may involve dramatic changes such as metamorphosis.

Present study

The review above gives an overview about what children and adults may know about growth in biological kinds. Preschoolers have some implicit understanding that growth involves non-dramatic changes such as an increase in size. More importantly, children also understand the importance of proportional changes in growth to some extent. Adults seem to be aware of these concepts at least when judging human-like growth.

The present proposal is to extend our knowledge about children's and adults' concepts of biological growth. This is aimed at understanding the degree to which children and adults use general principles of growth that apply across different species (all species increase in physical size with growth and development) and use other general principles that do not apply across all species (for all species of mammals the head-body proportion becomes smaller with physical growth, but for reptiles this proportion is relatively constant over the course of physical growth). My examination of these issues can be organized around these four specific questions:

(i) What do preschool children, third-graders and adults know about patterns of physical growth and development across different mammal, reptile and novel species of animals? Do they have explicit knowledge so they can state rules about the principles they believe underlie physical growth?

In order to assess their implicit use of growth principles, I asked children and adults to look at pairs of pictures of animals, and to say which looks older and which looks younger. Then, to assess their explicit knowledge, I interviewed them asking what rules and principles they may have had in mind to guide their decisions. I expected younger children to base their responses on what they know implicitly. For example, young children may implicitly infer size changes and proportional changes as important for growth, but size changes may be easier to articulate (explicitly) than proportionality. Adults on the other hand may be able to implicitly and explicitly indicate both size and proportional changes as important aspects of growth.

(ii) To what extent do children rely on size and/or proportion when comparing the age of animals in different stages of growth? It is clear from past research that children seem to have a general rule that size increases during growth[3]. However, do they understand that size increases globally for some species (i.e., reptiles) whereas for other species (i.e., mammals) the body-size increases more than head-size? In other words, do young children understand proportional change, and if so, how do they generalize this principle?

In order to assess this, on some trials participants were shown pictures of animals that differed in size and proportion, some where size was equated, some where proportion was equated and some where size was in conflict with proportion (see details below). I expected younger children to rely primarily on size but older children and adults to rely primarily on proportion.

(iii) How do these concepts change with age—i.e., what do older children and adults understand about size and proportional changes, both implicitly and explicitly, in different animal species? Do older children and adults understand that proportional changes are part of growth only in some species and not in others? Do they share these concepts with younger children or are they different?

(iv) How do children and adults generalize the principles they use to judge growth? That is, how do they judge growth in unfamiliar, novel animal species bearing little resemblance to real animals?

Design

The present study consists of three experiments. Table 3 provides a list of the animal species that I propose to use in Experiments 1 and 2. I determined the specific species by informally interviewing fellow students about common mammals and reptiles. Among the

[3] Throughout the present study I mean a change in stature (i.e., body-height or body-length of the animal) as indicating size changes.

familiar mammals that the students mentioned, I selected the particular species listed above as being similar to humans (apes and monkeys), animals that were typically pets (dogs) or domesticated (cows and horses). Among reptiles, the animal species listed in Table 3 are the most common names that many students mentioned (e.g., crocodiles, snakes, lizards and turtles). As is obvious, the important difference between the two classes in terms of growth is the proportional change in mammals.

Table 3: Types of animals used in the present study and a summary of biological changes during growth in these animals

Changes	Size	Head: body proportion	Metamorphic
Class: Mammalia			
Order: Primates			
1. Gorilla	Increase	Head smaller, body larger	N/A
2. Monkey	Increase	Head smaller, body larger	N/A
Order: Carnivora			
3. Dog	Increase	Head smaller, body larger	N/A
4. Fox	Increase	Head smaller, body larger	N/A
Order: Artiodactyla			
5. Cow	Increase	Head smaller, body larger	N/A
6. Horse	Increase	Head smaller, body larger	N/A
Class: Reptilia			
Order: Crocodilia			
1. Crocodile	Increase	No change	N/A
Order: Squamata			
2. Python	Increase	No change	N/A
3. Cobra	Increase	No change	N/A
Order: Testudines			
4. Lizard	Increase	No change	N/A
5. Chameleon	Increase	No change	N/A
6. Turtle	Increase	No change	N/A

Experiment 1 is designed to find out about children and adult's knowledge of physical growth and development in mammalian species; experiment 2 in reptile species and experiment

3 in novel species. Across the different trials of each experiment, subjects will be asked to look at a pair of pictures, and then to say which of the two appears to be older, and which younger. Participants will be tested on four kinds of trials where the pair of pictures will be determined using the following rules:

- **Same-size sets**: Each picture in the pair will be of the same size as the other. The pictures will however, show different proportional change: one with larger torso and smaller head, and one with larger head and smaller torso.
- **Mega-baby sets**: Each picture in the pair will show the same animal with the same proportions (i.e., with large head and smaller torso), but one picture will show an enlarged version.
- **Conflict sets**: Each picture in the set will be of different size, however the size will conflict with the proportional change. Thus one picture will be smaller but show the animal with a small head and larger torso (i.e., adult-like depiction). The other will be larger but show the animal with a large head and smaller torso (i.e., baby-like depiction).
- **No conflict sets**: Each picture will be of different size, but the larger picture will show adult-like proportional change, and the smaller picture will show baby-like proportional change.

Each participant will be tested on each kind of set with all six mammal species and human pictures (Experiment 1), or six reptile or novel species (Experiments 2 and 3). Trials will be presented in a random order across participants, with the constraint that no more than two successive trials are from the same animal species, and use the same kind of set. In each trial, participants are required to make a forced choice in determining which picture depicts the older and which the younger animal. Participants' responses will be recorded (i.e., pair-wise judgments), and analyzed for the principle they used in determining the age. Responses will be classified according to the principle used as following the “size rule,” the “head proportion rule, “both rules” or “random.”

The statistical analyses of the data will be designed to answer four questions for each experiment:

The first question is do the subjects of a given age use the “size rule” and the “proportion rule” reliably in the stimulus conditions where the pairs of contrasting stimuli differ only according to one rule? In order to answer questions about whether the judgments made by subjects in a given age group reflect the use of the “size rule” or “proportion rule”, the trials where the particular rule could be used without the other rule applying will be aggregated, the percentages reflecting rule use will be calculated, and the scores of the subjects in a group will be tested against chance using t-tests.

The second question is whether the age groups differ in the relative proportions of trials where their responses follow the “size rule” and where their responses follow the “proportion rule’? F-tests will be used to answer these questions.

The third question is whether for each age group, redundancy helps or hinders the consistency of using the “size” and “proportion” rules? To answer this question, only the responses in the “no-conflict” condition will be tested. The resulting scores can be tested against chance, or against the scores derived from trials where only one rule could operate, and they can be compared across age groups.

The fourth question is how do the subjects in each age group deal with the conflicting cues? To answer this question only the responses in the “conflict” condition will be used. The resulting scores can be tested against chance, or against the scores derived from trials where only one rule could operate, and they can be compared across age groups.

The fifth question is what rules do participants state explicitly? To answer this question participants' explicit responses will be coded, the codes categorized and the frequencies of the codes will be analyzed for age differences.

CHAPTER II

EXPERIMENT I

This study examines children's and adults' understanding of biological development in different classes of mammals, specifically the seven species mentioned in Table 3. My specific questions in this study are:

1. Do preschoolers, school age children and adults implicitly use the size rule when judging physical growth for these classes of mammals? That is, will they judge that the larger versions are older?
2. Do preschool and school age children and adults implicitly use the proportion rule when judging physical growth for the mammals? That is, will they know that growth involves changes in body proportions, such that the juveniles pictured will have larger heads and smaller bodies, whereas the mature forms will have smaller heads and longer bodies? A related question is (2a) do children and adults weigh proportional changes differently from changes in size – i.e., when the pictures depict animals equal in size (size-equal sets), or animals with adult-like proportions smaller in size than animals with child-like proportions?
3. What explicit rules do participants state about growth? What are their reasons for indicating that one is the older animal and the other, the younger animal? Do they explicitly state rules about size changes, and proportional changes? Do they indicate other kinds of changes?

All the mammal species selected for this experiment change in size. Most animals acquire new features during development resulting in morphologically more complex adult forms (refer to Table 2 for a list of changes during growth in different animals). Further, growth in all these species is non-dramatic in the sense that the young organism looks very similar to the mature form compared to species like insects that undergo metamorphosis. However, a remarkable change, unique to mammals, is the proportional growth—the development of head vs. trunk differs with time, the head remaining somewhat stable in size while the trunk becomes larger and longer over time.

Past research shows that children, by the age of four years, have a fundamental implicit understanding that animals increase in size during growth. Children also learn about different animals in school—the curriculum objectives for kindergarten classes and elementary school grades include understanding life-cycle changes in familiar animals. It is important to examine children's concepts about growth both when they have informal knowledge and later when they have formal instruction through schooling, in order to study the development of these concepts. This study looks at both preschool and school age children's use of principles about physical growth in addition to adults' use of these principles.

A fundamental concept that most children and presumably most adults have is that all organisms undergo changes in size. While adults may have general expectations about proportional changes in familiar organisms, children's expectations may be limited and tied to particular species. In this study, participants will be presented with pairs of pictures and asked to judge their relative ages. The pictures will show the "baby" and the mature form from each species. Additionally the sets of pictures will be based on the following rules:

- **Same-size sets**: Each picture in the pair will be of the same size as the other. In the case of mammals, the pictures will show different proportional change (one with larger torso and smaller head, and one with larger head and smaller torso).

- **Mega-baby sets**: Each picture in the pair will show the same animal with the same proportions (i.e., with large head and smaller torso), but one picture will show an enlarged version.
- **Conflict sets**: Each picture in the set will be of different size, however the size will conflict with the proportional change. Thus one picture will be smaller but show the animal with a small head and larger torso (i.e., mammalian adult-like depiction). The other will be larger but show the animal with a large head and smaller torso (mammalian baby-like depiction).
- **No conflict sets**: Each picture will be of different size, but the larger picture will show adult-like proportional change, and the smaller picture will show baby-like proportional change.

The following are my hypotheses:

1. On the *no-conflict* (where size changes match proportional changes) and the *same-size* (where the only change shown is a proportional change) conditions, I expected most adults to judge the appropriate ages of mammals by selecting the animal with the larger head and smaller body as the baby. Children may also judge the appropriate ages in most mammal species by size or proportion in the no-conflict condition and by proportion or be inconsistent in the same-size condition.
2. In the *mega-baby* condition (where the "mature" form is an enlarged "baby"), I expected that adults might decide that the larger version is the older animal. On the other hand, if adults expected proportional differences to be essential to mammalian growth, they may voice an inability to select one animal as older or younger and hence be random in their responses. Similarly children may select the larger version as the older animal, or may judge inconsistently on different trials.

3. In the *conflict* condition (where size is mismatched with proportional changes), I expect that most adults and older children will again be able to judge appropriate ages for mammals. Younger children may have difficulty in this condition. These children may select randomly (i.e., select the "baby" picture on some trials, and the "adult" picture on some trials) or follow a size-only rule in which case they will select the animal that is larger (but shows baby-like proportions).
4. Participants from all ages will be able to explicitly indicate size changes. Older children and adults may also verbalize their knowledge about proportional changes. All participants may indicate other changes from observing the differences in the pictures.

Method

Participants

Ten 4-5-year-old children (Mean Age = 4;7 years; 4 girls), 10 8-10-year-old children (Mean Age = 9;3 years; 4 girls) and 10 adults (Mean Age = 25 years; 3 females) were recruited. Children were from preschools and elementary schools in the neighborhood. Adults were recruited from among the student population of Vanderbilt University.

Materials and procedure

Picture sets of the seven mammal species in the four different stimulus conditions were constructed. These pictures were black-and-white line drawings with minimal shading to eliminate information such as skin coloring, which may indicate age other than size and proportion. There were no additional features to provide cues about relative size—we wanted subjects to base their judgments on the pictures, and to minimize their dependence on previous knowledge. Each sheet depicted the animals in one of the four conditions, and had two pictures, one below the other, in 5” x 5” boxes. Appendix A gives the stimulus pictures (from all species, in all trial conditions) used in this study, albeit in a reduced version.

Participants were tested in a quiet room in their preschool/school or on campus at the University. Preschool and school children were familiarized with the task setting. The experimenter then said, “We are going to look at some pictures of animals. On each sheet you’ll see two pictures, one below the other. Look at these really well, and then tell me which is the baby and which is the mommy. Ok?” On the first few trials, the experimenter repeated the question “Can you tell which is the baby and which is the mommy?” after she showed the picture sheets. Responses were coded for which picture (top/bottom) were indicated to be the baby or adult. Each pair of “correct” judgment got a score of one. Order of presentation of test trials and control trials were randomized. At the end of the last test trial, the experimenter brought out one sheet from each test condition (randomly selected) and asked the participant, “Do you remember seeing this picture? Can you tell me which is the baby and which is the mommy again?” After participant responded, she asked them “Why did you pick this (indicating the appropriate response) as the mommy and this as the baby? What made you think this is the grown-up and this is the baby?” These responses were written down, and coded for the principle/s used in judging age. With the preschool and school children, the entire experiment session was digitally videotaped. With adults, the experiment session was audio taped.

Results

To recap, the main questions we asked in this experiment were whether participants use the size rule i.e., understand that size increases with age, whether they use the proportion rule i.e., understand that proportion changes with age, whether they weigh proportion over size when determining age and what is the nature of their explicit responses. Each of our four stimulus conditions were configured to answer these questions so I present the results separately first, then results of participants' explicit knowledge, and discuss implications when these results are taken together.

Table 4 presents the principles that can be used in each stimulus condition. Principles we considered appropriate are presented in the top row. That is, in the no-conflict trials an appropriate response would be indicate the smaller (by size) or the animal-with-the-larger-head (by proportion) is younger; in the mega-baby trial to indicate the smaller animal (by size) is younger; in the same-size trial to indicate the animal-with-the-larger-head (by proportion) is younger; and in the conflict trial to indicate the animal-with-the-larger-head (by proportion) is younger. If participants answered according to these principles, the paired response was given a score of one. Participants can thus score a maximum of 28 with each of the 7 species in each of the 4 stimulus conditions.

Table 4: Principles that may be used in determining age in the four types of trials

Principle Used	*No Conflict*	*Mega-Baby**	*Same-size***	*Conflict*
Appropriate	Size or Proportion	Size	Proportion	Proportion
Inappropriate	Random	Random	Random	Size

* Proportion is irrelevant ** Size is irrelevant

Table 5 presents the means for the three age groups in the four stimulus conditions. Across all trials, a multivariate analysis of variance on the total scores as dependent variable with sex and age as factors revealed no significant effect of sex, or sex by age interaction, *F*s < 1, but a main effect of age, F (2, 24) = 10.6, $p < .001$[4]. The results reported below are for each trial type.

Table 5: Means (and Sds) of appropriate responses of the three groups in the four different trial types with pictures of mammals

Agegroup	*No Conflict*	*Mega-Baby*	*Same-Size*	*Conflict*
Preschool children	**7.00** (.00) (100%)	**6.90** (.32) (99%)	**5.60** (1.23) (80%)	**1.50** (1.35) (21%)
School age children	**6.91** (.30) (99%)	**6.82** (.41) (97%)	**6.64** (.51) (95%)	**4.82** (1.25) (69%)
Adults	**6.90** (.32) (99%)	**5.10** (2.08) (73%)	**6.70** (.68) (96%)	**6.20** (1.14) (89%)

Note: N =10 in each age group; the maximum score in any condition is 7 (i.e., 1 each for the 7 species).

No-conflict trials

The stimuli in these trials depicted two pictures on each sheet, one showing a smaller animal with mammalian child-like proportions and a bigger animal with mammalian adult-like proportions. Thus, participants can use the size principle (smaller animal is younger) or

[4] Separate correlations for the three age groups on scores for each trial type were mainly not significant.

proportionality (animal with big head and small body is younger) to provide appropriate responses. Participants in each age group were at ceiling on these trials, all *t*s (df = 9) greater than chance, $p < .001$. A one-way analysis revealed no significant difference in age groups, $F(2, 27) < 1$, $p > .5$. These results indicate that participants from all age groups understood the task requirements, and used one or more principles in determining the relative ages of the animals depicted.

Mega-baby trials

Stimuli in these trials depicted two pictures, both with mammalian child-like proportions, one smaller in size and the other bigger. Indicating the smaller picture as the baby and the bigger picture as the adult was coded as appropriate response. The preschool and school children were at ceiling on these trials, *t*s greater than chance, *p*s < .001. Adults' responses were also above chance, but a one-way anova revealed a main effect of age, $F(2, 27) = 7.08$, $p < .01$. Post-hoc Tukey's HSD tests revealed that adults were significantly different from preschoolers' ($p = .01$) and school children ($p = .01$) in using size to determine age on these trials. While both groups of children responded to the task requirements, adults probably had difficulty in indicating one animal as older when they perceived both animals to have the same child-like proportions. In fact, many adults commented that both animals looked alike, and demurred from assigning an age label to either. They did so only when the experimenter reminded them to make a choice.

Same-size trials

Stimuli in these trials depict two animals, both similar in size but one with the mammalian child-like proportions and one with mammalian adult-like proportions. Responses were coded as appropriate if participants indicated the animal with the larger head and smaller body as younger and the animal with the smaller head and larger torso as older. Preschool and school children and adults were able to use the proportional differences to guide their responses. Preschoolers' responses were well above chance, as were school children's and adults' responses, *t*s > 5.0, $p < .001$. A one-way analysis of variance revealed a significant difference among the three age groups, $F(2, 27) = 5.1$, $p = .01$. Preschoolers were found to be significantly different from both school age children and adults (post-hoc Tukey's HSD tests, $p < .05$). Preschool children were able to use proportional differences to guide their inferences about age, but they were not as unequivocal as older children and adults.

Conflict trials

Stimuli in these trials depict two animals: one smaller but with mammalian adult-like proportions, and one bigger but with mammalian child-like proportions. Size was thus in "conflict" with the proportion. Responses were coded as appropriate if participants indicated the smaller animal as older (based on the head-body proportion) and the bigger animal as younger. School children and adults were significantly above chance (both *t*s >1, $p < .01$). Preschool children were well below chance, i.e., they chose the smaller animal as younger, basing their responses on size ($t(9) = -4.7$, $p < .001$). One-way analysis of variance revealed a significant age difference ($F(2, 27) = 37.5$, $p < .001$). Preschoolers responded exclusively based on size and thus were different from both adults and school children (Tukey's test, $p < 0.001$). Interestingly, the difference between school-age children's responses and adults' responses approached significance ($p = 0.06$), indicating that school children were not using the proportion principle as much as adults did. Indeed, size seems to be a dominant factor in children's knowledge about growth, especially when the effect of proportion is placed in contrast to size.

Species-type responses

As a final step in analyzing the implicit data, we compared children's and adults' responses across the individual species. A one-way ANOVA revealed a main-effect of age with species 2, species 3, species 5, and species 7. Further post-hoc Tukey's tests showed that preschool children differed in their responses on these species from both school children and adults ($p < 0.05$). The other two age groups did not differ from each other.

Explicit responses

At the end of the judgment-of-age trials participants were shown four pictures-sets, one each from the different trial conditions, but from different species and asked to verbalize why they thought a particular animal was an adult or baby and vice versa. Their utterances were coded using the scheme in Appendix D. We categorized any response that referred to the *absolute* size of the animal or any part/feature under the first code for size (e.g., "this is older because it is bigger," or "this is younger because it is small, has small eyes and ears"). We categorized any response about the *relative* size (e.g., "this is younger because it has a bigger head, and short legs; and this [pointing to the other picture] is older because it has a small head but bigger body,") as explicitly referring to proportionality. We also categorized any response that referred to proportional differences but not in complete statements like in the examples above, as *directing attention* to a feature of proportionality (e.g., "this is younger because it has a big head and babies have big heads"). Each utterance was given one of the codes mentioned in the scheme in order to effectively categorize all of their explicit knowledge that was revealed in these trials. For example if a participant said, "This one is bigger, has longer legs, a longer tail and has larger ears" they would get four codes: (i) for overall size, (ii) for mentioning the legs, (iii) for mentioning the tail, and (iv) for mentioning the ears. The experimenter coded all utterances and was blind to the species kind and subject details, but not the animal (older or younger) that the subject was talking about. Another coder also blind to the species type and subject details coded utterances made by 20% of the subjects. Inter-coder reliability was approximately *86%*, (chance agreement = 50% when the subject referred to size of any body feature) and differences were resolved by discussion. All utterances that were made under a major code category (e.g., 1a, 1b, 1c and so on) were summed under the major category (e.g., 1a + 1b + 1c = [a score of] 3 [for code 1]). These summed responses are the basis for the analyses reported below. Table 6 gives the mean proportions of these coded responses across the different age groups.

A one-way analysis of the total number of utterances revealed no significant differences among the age groups. However there were differences when the utterances coded for size, proportion, proportion features, relevant features and other were analyzed:

a) There was a main effect of age in utterances indicating size differences between the two pictures depicted, F (2, 28) = 8.0, $p < .01$. Tukey's HSD post-hoc tests showed that preschoolers were different from school children and adults (ps< .05). Younger children thus made a larger percent of utterances about size differences.

b) Adults made explicit references to proportionality; both school children and preschoolers did not. Note, this code was granted only when the participant made an explicit reference to the head-body ratio, in both the pictures depicted, and indicated that as a factor differentiating growth.

<u>Table 6: Mean proportions of utterances (and SDs) about mammals summed across the four trial conditions for each age group</u>

Agegroup	Total number	% size (a)	% prop. (b)	% prop. features (c)	% rel. features (d)	% other (e)
Preschool	11.6 (7.01)	49 (26.7)	0 (0.00)	9 (16.6)	12 (12.4)	30 (22.7)
School Age	16.2 (5.69)	27 (14.0)	0 (0.00)	18 (13.7)	18 (14.5)	35 (8.3)
Adult	15.8 (6.81)	14 (14.1)	4 (6.1)	33 (11.7)	10 (8.1)	36 (13.0)

<u>Note</u>: The second column (Total number) is the mean number of utterances; the rest are proportions. % size= percent of expressions coded as indicating size changes; % prop.= expressions coded as head-body proportional changes; % prop. features= expressions coded as features that may indicate proportionality; % rel. features=expressions coded as relevant features; and % other=expressions coded as “irrelevant,” “don’t know,” and “can’t code.” Columns a through e total 100, except 2% of school children’s responses and 3% of adults’ responses indicated that both animals (on some stimuli) were identical.

c) Again, age was a significant factor in explicit knowledge about features that indicated proportionality, F (2, 28) = 7.1, $p < .01$. Tukey’s post-hoc tests showed that only adults made larger percent of explicit responses than both the younger groups of children ($p <$ .01).

d) There were no significant age differences in explicit knowledge about features like the presence of horns, droopy ears etc that may indicate growth in some species; or in utterances that were grouped under the “other” category, including irrelevant utterances, un-codeable utterances and the scant instances when participants told us they did not know any differences.

Discussion

We began this experiment as a first systematic study of understanding what young children, grade school children and adults know about growth in familiar mammal species, especially with regard to changes in size, changes in the head-body proportions, what they know implicitly and what they can explicitly articulate. The results reveal that most participants implicitly know that the mammals studied here grow bigger, and that their bodies grow bigger to a larger extent than does their head, albeit with some caveats. The younger participants did not reliably indicate proportional differences as the basis for age differences when these proportions were placed in contrast to size differences. Further, they were more ready to accept that growth is indicated when the organism becomes larger with no accompanying proportional change, than were adults. These results replicate earlier findings (Hickling and Gelman, 1995); Rosengren et al. 1991) but differ in important ways from previous studies.

First, previous studies have looked at growth in living things as one of the properties that define being alive. The few studies that have examined concepts of growth in depth (e.g., Todd & colleagues, Dehart et al., Langford (1983) investigated concepts of proportional changes in humans, not mammals or other animals in general. The current study looked at what people know about proportional changes in familiar mammals, not just humans. Even the youngest participants in this study consistently knew that head-body proportions change with growth, as revealed by their performance on the *same-size* trials.

Second, adults and older children were more consistent with this view than were the youngest children. On the *conflict* trials, the preschoolers were more likely to use size as an indicator of age, than proportion. Preschoolers' performance on this task could have been due to a strong preexisting bias toward size as a factor that reliably correlates with growth.

Alternatively the stimuli were two-dimensional line drawings that are not as informative as real-life examples or three-dimensional images. Unfamiliarity with the pictorial stimuli depicting size differences could have driven these results with the preschoolers. However, all participants, including preschoolers, were at ceiling on the trials involving the pictures of human baby and adult. Some children even remarked that the small human adult looked small because s/he was "far away," whereas the human baby looked big because s/he was nearer. This sophisticated reasoning belies the explanation that the stimuli were not informative.

Third, on the *megababy* trials adults were not as consistent as either group of children in judging that the bigger animal as older. Adults were loath to accept that the bigger animal is older: they could "see" that the bigger animal was merely the smaller animal blown-up. Several adults selected the smaller animal as older on some trials when the experimenter urged them to pick one as the older and another as the younger animal. However, their performance could be taken as an indication of the primacy of proportionality in their concepts of growth. Adults seem to use the proportion rule consistently, and weighed it over size changes (for example, their performance on the conflict trials). Thus adults' performance on the megababy trials may seem to be less than an "optimal" level, but only when we consider these with the performance of children. Preschool children relied on size changes, hence they were at ceiling on these trials. Preschoolers showed almost no consideration to the proportional changes that were remarkably absent. School children's performance on these trials is not different from preschoolers' but they may have just complied with the experimenter's request without any conviction that the bigger animal looked older.

Finally participants' explicit responses reveal that preschoolers know and can articulate size changes more so than any other age group. Indeed 49% of their responses are about size changes compared to school children's 27% and adults' 14%. By contrast, adults articulated concepts of proportionality- 37% of their responses were about proportional changes, compared to 18% or lesser by children. This is in concert with the implicit responses of all groups of participants. However, all participants especially the preschool children were able to implicitly judge by proportion, more than their explicit responses indicate.

Experiment 1 studied children and adults' concepts of growth concerning mammals. But mammals, while possibly being the most familiar species are but a fraction of the animal kingdom. Several species of birds, reptiles, fishes, insects and other organisms are popular pets. Besides, the media provide excellent information about different families of animals. Reptiles are unique among the vertebrates: they do not show the proportional differences during growth as mammals; they are born as miniature adults. Experiment 2 therefore looks at what children and adults know about reptiles.

CHAPTER III

EXPERIMENT II

In this experiment, I investigated children and adults' concepts of growth about reptilian species. Reptiles differ from mammals in their growth patterns in many ways, but the most significant aspect of concern here is that mammals show a proportional change during growth and reptiles do not. In other words, reptilian species are born as "miniature adults" although they do show changes in other aspects (e.g., skin changes) that are similar to mammals.

Folk notions of growth in reptiles, however, do not seem to take into account this absence of proportional changes. One example is from cartoon figures and pictures of reptiles in children's books that depict young reptiles with large heads and prominent eyes, capitalizing on the mammalian aspects of "cuteness" (see Pittenger & Todd, 1983). It will be interesting to find out whether people endorse this folk notion or have a differentiated understanding of growth in reptiles, albeit implicitly. Extending this to children, do school age children and preschoolers know that proportional changes are not part of reptilian growth?

The stimuli in this experiment were picture-sets depicting reptiles from the six species mentioned in Table 3. Each picture set showed the reptiles in one of four conditions: no conflict, mega-baby, same-size and conflict, and constructed closely following the principles used in Experiment 1 with mammals. The "baby" reptiles were manipulated to look like mammalian babies, i.e., with a proportionally larger head and smaller torso than the adult reptiles; the "adult" reptiles were simply renderings of full-grown reptiles and not manipulated. Thus in the no-conflict condition the "baby" reptiles were smaller in size but also proportionally different; in the megababy condition, the "adult" reptiles were just enlarged versions of the baby reptiles; in the same-size condition, the two pictures were of the same size but differed in proportion, just as in mammals; and in the conflict condition the "baby" reptiles were depicted as larger than the "adult" reptiles. A complete set of reptiles in the four conditions is presented in Appendix B.

The main hypotheses in this experiment were:

1. On the *no-conflict* condition, I expected most participants to judge the appropriate ages of reptiles by selecting the smaller animal as the baby and the larger as the adult (i.e., judge by size).
2. In the *mega-baby* condition (where the "mature" form is an enlarged "baby"), I expected that adults and children would decide that the larger version is the older animal, or select randomly as in the case of mammals.

   In both these conditions, size information is available. I expected participants to use size as a guiding principle in the absence of more discerning information or knowledge.
3. In the *same-size* condition, I expected that adults and older children would judge the animal with the bigger head as the baby (just as in the case of mammals) and the animal with the smaller head as the adult. Preschool children may be inconsistent in their choices, as might participants of other ages.
4. In the *conflict* condition (where size is mismatched with proportional changes), I expected that most adults and older children would use proportion to judge the ages (just as in mammals). Preschool children may have difficulty in this condition. These children may select randomly (i.e., select the "baby" picture on some trials, and the "adult" picture on some trials) or follow a size-only rule in which case they will select the animal that is

larger (but shows baby-like proportions). Older participants may follow this pattern as well.

5. I expected participants' explicit responses to follow a pattern similar to the first experiment: all participants may articulate knowledge about size changes, with preschoolers talking more about size changes than any other age group, and adults indicating proportional changes more. School children may reveal some explicit knowledge about proportionality. However, if adults and older children know that reptiles do not show any proportional changes, they may be ambivalent in their responses.

Method

Participants

Ten 4-5-year old children (Mean age= 4.3 years; 6 girls), ten 8-10-year old children (Mean age= 8;11 years; 5 girls), and ten adults (Mean age= 23 years; 8 females) participated. Preschool and school-age children were recruited from preschools and schools in the neighborhood. Adults were recruited from the Vanderbilt community.

Materials

As mentioned above, stimuli were pictures of reptiles from the following six familiar reptilian species: chameleon, lizard, cobra, python, crocodile, turtle. Each sheet depicted two animals (both from the same species) one below the other, just as in Experiment 1. Similarly, pictures were constructed to depict the animals in four trial conditions: no-conflict, mega-baby, same-size and conflict. In all the pictures, the reptilian "baby" was constructed according to mammalian baby in terms of proportion, i.e., with a larger head and smaller torso than the adult animal.

Procedure

Participants were tested in a quiet room on their respective school campuses, and the session lasted about 10 minutes. The procedure was similar to that in Experiment 1, except pictures of reptiles were used. Participants were asked to judge which was the "baby" and which the "adult/grown-up" on each sheet. The different trial conditions were randomized. At the end of the trials, participants were tested on four pictures (randomly selected to represent each trial condition) and asked to verbalize why they thought a particular animal was the baby or adult. Test sessions were videotaped with children, and audio-taped with adults.

Results

The main questions in this experiment were whether for reptiles participants would use size to judge age (when size information is available), whether they will use proportional differences to judge age (when it is available), and whether they will weigh proportional changes more than size changes in determining age. All participants were tested in the four different stimulus conditions with pictures of reptiles. I present results for each stimulus conditions below, and for the different species next. As in Experiment I, the MANOVA revealed no effects of sex, or sex by age interaction. Results for analyzed for each trial condition. Table 7 gives the means and standard deviations of all age groups in the four different conditions.

No-Conflict trials

Participants' judgments on these trials may be based on size (e.g., smaller is younger) or proportion (e.g., larger-head-to-body-proportion is younger) since both these information are available in the stimuli. Preschoolers were at ceiling on these trials, indicating that they understood the task requirements. School children and adults were slightly below ceiling but they scored well above chance (ts >10.0, ps < .001). A one-way ANOVA showed a main effect of age (F (2, 27) = 3.7, p < .05); Tukey's post- hoc test revealed that this was due to preschoolers responding significantly differently from adults (p < .05). This shows that young children found these trials unequivocally easy, while adults may have confused some of these trials with the conflict trials where size changes are depicted.

Mega-Baby trials

These trials involved stimuli which depicted one animal as larger than the other, but with the same proportions. Thus only information about size changes was present. Participants from all ages were almost at ceiling on these trials; there were no significant age effects. Children and adults clearly knew that smaller animals were younger.

Same-size trials

These trials involved pictures that showed both animals of approximately the same size but one with a larger head-to-body proportion, such as mammalian babies. Information about size changes was not definitive; information about proportional changes was present. Preschoolers' responses were significantly below chance, t (9) = -11.3, p < .001, showing that they were not using proportional changes to judge age; adults' responses were significantly above chance, t (9) = 3.0, p = .02, indicating that they were using proportional changes to judge age. Participants' age was thus a significant factor, F (2, 27) = 10.5, p < .001. Unlike the preschoolers and adults, school children's responses were not different from chance, t (9) <1.0, p > 0.1 – this was due to roughly 50% of the children who responded above chance (i.e., they made 4 or more appropriate responses) and the others responded well below chance[5]. The post-hoc test showed that preschoolers made significantly fewer responses by proportion than adults, p < 0.05. The other between-groups differences were marginally significant. Adults seem to be consistent with their counterparts who responded to pictures of mammals, using proportion to judge age. Preschoolers and school children did not reliably use proportional changes as indicative of age.

Table 7: Means (and Sds) of appropriate responses of the three groups in the four different trial types with pictures of reptiles

Agegroup	*No Conflict*	*Mega-Baby*	*Same-Size*	*Conflict*
Preschool children	**6.00** (.00) [100%]	**5.90** (.32) [98%]	**1.30** (.48) [22%]	**0.0** (.00) [0%]
School age children	**5.64** (.51) [94%]	**5.82** (.60) [97%]	**2.64** (1.91) [44%]	**0.73** (0.91) [12%]
Adults	**5.4** (.70) [90%]	**5.10** (1.3) [85%]	**4.00** (1.1) [67%]	**4.60** (1.71) [76%]

Note: N =10 in each age group; the maximum score in any condition is 6 (i.e., 1 each for the 6 species).

[5] Individual differences were rare. Subjects in all experiments were similar in responding across different trial types.

Conflict trials

Pictures in these trials showed one larger animal with mammal-baby-like proportions, and a smaller adult. The size change was misleading; the proportional change indicated growth according to a mammalian pattern. Preschoolers and older children predominantly chose the smaller animal as older, thus using relative size to judge age (t (9) = -8.3, $p < .001$ with school children). Adults were moderate in expecting size changes to indicate growth, but their responses were not different from chance (t (9) = 1.1, $p > .3$). There was thus a main effect of age, F (2, 27) = 29.5, $p < .001$. As expected, the post-hoc test revealed preschoolers and school children to be significantly different from adults ($p < .001$) but not from each other. Children seem to more readily accept that smaller size indicates a younger organism regardless of the proportional change. Adults on the other hand, seem to have some difficulty doing so, possibly because of their knowledge about the proportional change in mammals and some knowledge that reptiles do not show these changes.

Species-type responses

Analysis of participants' responses to each species of reptiles indicated that preschoolers, older children and adults differed significantly in their responses to species 3, species 4, species 5, and species 6, all Fs > 5.0, ps < .05. On further examination, the post-hoc tests showed that preschoolers made significantly fewer appropriate responses than adults with all the four species mentioned above (Scheffé ps <.05), and fewer appropriate responses than older children with species 4 ($p < .05$). Older children differed from adults on species 3 and 6 (Tukey's $p < .05$), but they did not make significantly fewer responses than adults on the other species.

Explicit responses

Participants' explicit verbalizations about each picture set were coded according to the scheme presented in Appendix D, and as described in Experiment 1. The experimenter coded the transcribed responses from each participant, and was blind to the subject and species kind details. Another blind coder coded responses from 20% of the participants (i.e., 6 participants) and inter-rater reliability was 90%. Differences were resolved by mutual discussion. Table 8 gives the mean proportions of these coded responses across the different age groups.

Table 8: Mean proportions of utterances (and SDs) about reptiles summed across the four trial conditions for each age group

Agegroup	Total number	% size (a)	% prop. (b)	% prop. features (c)	% rel. features (d)	% other (e)
Preschool	9.9 (3.2)	77 (18.8)	0 (0.00)	1 (3.5)	9 (13.1)	13 (16.9)
School Age	12.4 (3.4)	50 (19.4)	0 (0.00)	15 (13.5)	19 (13.5)	13 (12.0)
Adult	9.2 (3.0)	48 (19.6)	2 (4.9)	12 (17.8)	1 (2.4)	22 (20.7)

Note: The second column (Total number) is the mean number of utterances; the rest are proportions. % size= expressions coded as indicating size changes; % prop.= expressions coded as head-body proportional changes; % prop. features= expressions coded as features that may indicate proportionality; % rel. features= expressions coded as relevant features; and % other= expressions coded as "irrelevant," "don't know," and "can't code." Columns a through e total 100, except 3% of school children's responses and 15% of adults' responses indicated that both animals (on some stimuli) were identical.

A one-way analysis of variance of the total number of utterances revealed that age was marginally significant, F (2, 27) = 2.8, p = .08. As in Experiment 1, analyses of responses by the different codes showed significant results:

a) There was a main effect of age in participants' explicit verbalizations about size differences in the pictures of animals, $F(2, 27) = 5.7$, $p < .01$. Post-hoc Tukey's tests showed that preschoolers' responses contributed to this effect: they were different from both the school children and adults (both *p*s < 0.01). As Table 8 shows, a large portion of preschoolers' explicit knowledge is based on size differences, significantly more so than older children or adults.

b) There were no significant age effects in the responses that were coded as referring directly to proportionality, or in the responses coded as referring to certain features indicating proportional differences in the animals. Thus participants' explicit responses seem to follow their implicit judgments, as revealed by their performance on the same-size and conflict trials where proportionality indicated appropriate responses.

c) There was a significant age effect in the explicit responses that were coded as indicating the importance of features other than size and proportion as relevant to growth, $F(2, 27) = 7.2$, $p <.01$. As Table 8 shows, the school-age children's responses in this category were significantly different from adults' responses, $p < .01$. Older children seemed to notice differences in the pictures and voiced these differences, more than preschoolers or adults.

d) Finally there were no significant age differences in responses coded as irrelevant to the present questions about growth.

Discussion

We began with questions about the nature of children's and adults' knowledge about growth in reptiles, which does not show the proportional changes common in other vertebrates. As in Experiment 1, the specific questions were whether participants would use size changes in determining age; whether they would use proportional change to determine age, whether they would weigh proportions more than size and whether their explicit responses would reveal their knowledge of these factors.

This study has no precedence in the literature on children's concepts of growth, partly because concepts about reptiles have not been considered as a separate object of investigation. The results however reveal some interesting features about children's and adults' concepts about reptilian growth. As a first step, responses to the *no-conflict* trials indicate that participants understood the task requirements and were able to judge the ages of the animals depicted.

Responses to the *megababy* trials were also at ceiling, indicating that participants had no hesitation in selecting the smaller animal as younger and the larger as older. However, about 15% of adults' explicit responses were remarks about the identical nature of the two animals – thus they seem to realize that the pictures depicted the same animals differing in size, and had an expectation that the pictures ought to look different if they belonged to different ages. This is similar to the performance of adults in Experiment 1 with mammals: like the adults in that experiment, these adults seem to expect proportional differences to be integral to growth, little realizing that they were over-generalizing. In reality, reptiles do not show the proportional change that mammals do, but the proportion rule seems to be an implicit principle that adults have learned.

Responses to the *same-size* trials were interesting: adults seem to use the mammalian proportion principle to determine age, whereas preschool children *consistently* selected the animal with the big head as the older animal. Preschoolers seemed to be swayed by the strikingly large heads of the reptiles into selecting them as older, quite at variance with their counterparts in Experiment 1 who used the same principle to judge the mammals as younger. Preschoolers thus seemed to understand a larger "surface-area" indicates growth rather than stature, which was equated on the same-size trials. Third-graders were ambivalent in their responses – as mentioned earlier, this was due to some children responding above chance, and some below chance. Some third-graders then, seem to apply the mammalian proportion principle; others seem to respond similar to the preschoolers.

On trials where size was contra-indicated growth, i.e., on the conflict trials where smaller sized animals had mammalian adult-like proportions and bigger animals had baby-like proportions, both groups of children chose according to size. Even those third graders who judged the animal with the larger head as younger (in the same-size trials), chose the same animals (but larger in overall size) as older. When confused, children seem to use "smaller=younger; larger=older" as the default strategy in making age judgments. Adults were also conservative in their responses to proportion on these trials: most adults selected the smaller animal as the younger, although not all their responses were consistent with this strategy.

These results are comparable to participants' explicit responses about size and proportionality. The major portion of all responses was about size – 77% for the preschoolers, and roughly 50% with the other two ages. This is in tune with their implicit responses – participants judged by size on a large number of trials (the no-conflict, mega-baby, and conflict trials), and they articulated this principle as important in their judgments. By contrast only about 15% of school children and adults' explicit remarks were about proportionality, but they were not statistically different from the preschoolers' responses.

Taken together with the results from Experiment 1, a complex picture emerges: Our youngest participants clearly have a sense of size changes as important in indicating growth. They understand growth involves proportional changes, especially with mammals, but when pitted against size they conservatively revert to using size as a more reliable indicator. They also use head-size, when proportion was "unnaturally" manipulated on the reptiles.

Older children are more sophisticated in their responses: they use size changes, proportional changes even when proportion is conflicted with size (with mammals) but like preschoolers use size as a reliable indicator with the reptiles. Their explicit responses also indicate that these children use size change as the most common and reliable principle in determining growth. Older children's responses were somewhat similar to adults' responses in many cases: adults judged by size, and by proportion on the conflict trials with mammals. Adults differ on their responses to conflict trials with reptiles: they use the mammalian proportion principle, even when this manipulation is artificial on reptiles. However their responses were not different from chance levels, indicating that adults may have some knowledge that reptiles do not show a proportional change as mammals do. Alternatively, the stimuli could have cued them to this manipulation and they were unsure of the appropriate response.

Adults also differ in their explicit responses: they place importance on proportionality when judging mammalian growth, unlike both preschool and school children. When judging reptilian growth, adults made more responses about proportionality than children, but size concepts are dominant in their remarks.

Experiments 1 and 2 looked at children's and adults' responses to familiar animal species. While they reveal several interesting findings, the argument can be made that adults and children could have used their previous knowledge in concert with what the stimuli depicted, to respond using principles of size and/or proportionality on these different trials. That is participants could have had some implicit and explicit knowledge about changes during growth but could have learnt from the task stimuli as well. In other words, we do not have an unbiased estimate of what children and adults know about growth—an abstract notion of what changes are important in the growth of an organism without some knowledge about the organism's other characteristics that are correlated with growth. In order to test participants' general beliefs about growth, we need to use unfamiliar, imaginary, artificial animals. Such stimuli would render previous knowledge about the animals obsolete without removing what is essential in terms of concepts of growth and development that are common to all living things classified as animals. Experiment 3 is an attempt to resolve these issues, and obtain unbiased evidence about children's and adults' general concepts of growth.

CHAPTER IV

EXPERIMENT III

This experiment looked at children's and adults' concepts with imaginary animals. We tested participants on "made-up" animals in order to see if participants generalize concepts of growth when no pre-existing model is available. That is, with both mammals and reptiles, participants may have some idea of growth from real-life examples, through experience with animals, or from media information about the life-cycles of these animals. In order to find participants' abstracted general concepts, we need to test their knowledge when they have no preexisting notions about any particular animal.

All participants were tested on six novel species of animals, in the same four conditions as in the previous experiments. The pictures were constructed to depict unfamiliar animals in both upright positions (i.e., to resemble human-like creatures) and four-legged animals. The "baby" animals were constructed to have a larger head-to-body proportion than the "adult" animals.

The main hypotheses in this experiment were:

1. *No-conflict* trials: These being the control trials depict the "baby" animal as smaller in size and with mammalian proportions (larger head, smaller torso). Participants were expected to use either size or proportion to judge the age of the animals. Participants may however, be inconsistent in their responses.
2. *Mega-baby* trials: Pictures on these trials depicted two animals with the same proportions, one smaller and the other larger. Since size information is available,

participants were expected to base their judgments on size. Participants may also select randomly and not follow a principled selection pattern.

3. *Same-size* trials: Stimuli in these trials showed two animals of the same-size (thus size was not a reliable indicator of age), but different proportions: one had mammalian baby-like proportions, and the other adult-like proportions. Participants could use the proportion information, or be random in their choices.
4. *Conflict* trials: The pictures depicted two animals, one smaller than the other. However, the smaller animal had mammalian adult-like proportions (smaller-head-to-body ratio) and the larger animal had mammalian baby-like proportions. Thus size was misleading; proportion was a more reliable indicator of age. Older children and adults were expected to be sensitive to this deceptive nature of the stimuli and judge the age of animals by proportion, though they may go with size. Preschoolers were expected to make their selections based on size. All participants could follow an inconsistent pattern.

Method

Participants

Ten 4-5-year old children (Mean age= 4; 5years; 3 girls), ten 9-10-year old children (Mean age= 9;2 years; 5 girls), and ten adults (Mean age= 23 years; 3 females) participated. Preschool and school-age children were recruited from preschools and schools in the neighborhood. Adults were recruited from the Vanderbilt community.

Materials and procedure

As mentioned above, stimuli were pictures of unfamiliar, novel animals constructed to represent six different species. Although many definitions for the term species abound, it can generally be taken to refer to any group of organisms that can interbreed to produce a fertile offspring. In the present study, we constructed each species to be morphologically different from each other and unique in appearance while conforming to possessing external appendages that identify the organism as an animal (e.g., presence of limbs, tail). Some animals were depicted with two legs (i.e., human-like) and some with four limbs (like some mammals and reptiles). Each animal had some "alien" or artificial features, for example spiral antennae, or multiple eyes suspended outside the head.

Each sheet depicted two animals (both from the same species) one below the other. Pictures were constructed to depict the animals in four trial conditions: no-conflict, mega-baby, same-size and conflict. In all the pictures, the "baby" animal was constructed according to mammalian baby in terms of proportion, i.e., with a larger head and smaller torso than the adult animal. Appendix C presents a complete set of pictures of a novel animal.

Participants were tested in a quiet room on their respective school campuses, and the session lasted about 10 minutes. The procedure was similar to that in Experiment 1, except pictures of novel animals were used. Participants were asked to judge which was the "baby" and which the "adult/grown-up" on each sheet. The different trial conditions were randomized. At the end of the trials, participants were tested on four pictures (randomly selected to represent each trial conditions) and asked to verbalize why they thought a particular animal was the baby or adult. Test sessions were videotaped with children, and audio-taped with adults.

Results

As in previous experiments, the main questions of interest are whether participants will use size changes to judge growth in unfamiliar animals, and whether they would use proportional differences to guide their judgments when information about size changes is either absent or misleading. There were no significant sex or sex by age interaction effects. I present the results from the four stimulus conditions first, then from individual species and finally participants' explicit judgments. Table 9 presents the mean scores (and SDs) on the four conditions, and percentages below.

Table 9: Means (and Sds) of appropriate responses of the three groups in the four different trial types with pictures of novel animals

Agegroup	*No Conflict*	*Mega-Baby*	*Same-Size*	*Conflict*
Preschool children	**6.00** (.00) [100%]	**5.70** (.48) [95%]	**2.40** (1.35) [40%]	**0.3** (.48) [5%]
School age children	**6.00** (.00) [100%]	**5.82** (.41) [97%]	**2.55** (2.07) [43%]	**0.36** (0.81) [6%]
Adults	**5.4** (.70) [90%]	**4.10** (1.8) [68%]	**5.00** (0.9) [83%]	**3.50** (1.51) [58%]

Note: N=10 in each age group.

No-conflict trials

Stimuli on these trials showed one smaller animal and another larger animal. Participants seemed to have used the size information, both groups of children responding at ceiling and adults well above chance (t (9) = 10.9, p < .001). The one-way ANOVA revealed a significant main effect of age, F (2, 27) = 7.8, $p < .01$. Adults, surprisingly, did not use size to determine age as much as preschoolers and school children: the post-hoc Tukey's test was significant at $p < .001$. As with reptiles, adults may have confused these trials with the conflict trials where size does not indicate the appropriate age of the animals depicted.

Mega-baby trials

Pictures in these trials showed two animals of the same proportions, one smaller than the other. Thus information about size changes was present. Again, preschoolers and older children seem to have endorsed the size difference as an indicator of age, more so than adults. Both groups of children scored well above chance (t (9) > 10, $p < .001$), whereas the adults' responses were only marginally significant (t (9) = 1.9, $p = .08$). As expected the ANOVA showed a main effect of age, F (2,27) = 8.1, $p < .01$; as were the differences between adults and both preschoolers and school-age children (both post-hoc tests significant at $p < .01$).

Same-size trials

On these trials, participants saw pictures of two animals, both depicted as similar in size, but one with a larger-head-to-body proportion (like a mammalian baby) and the other with adult-like proportions. In the absence of information about differential size, preschoolers and third-graders were not different from chance, both ts < 1, $p > .2$. Adults, on the other hand, were more discerning in selecting the animal with the larger head as the baby, and thus scored significantly above chance, t (9) =6.7, $p < .001$. Once again, age was the main effect, F (2, 27) = 9, $p < .01$; the post-hoc comparisons showed that adults were different from both preschoolers and third-grade children (both Tukey's test ps $< .01$) but the latter two groups did not differ from each other.

Conflict trials

Stimuli on these trials showed two animals of different sizes, but the smaller animal had adult-like proportions and the larger animal had baby-like proportions. Size was misleading but proportion was a more reliable indicator of age. Preschoolers and school children judged the smaller animal as older, and were well below chance, $t\ (9) < -10$, $p < .001$. Adults were less prone to make their choices based on size, but their responses did not differ from chance, $t\ (9) < 1$, $p > .3$. Thus there was a main effect of age, $F\ (2, 27) = 32.6$, $p < .001$. Again, preschoolers were not different from older children, adults were different from both ages (Tukey's tests $p < .001$).

Responses by species type

Comparing responses by the individual species kind (one-way ANOVA with age as the between-groups factor), there was a main effect of age with species 1, species 2, species 3, and species 4, all Fs > 3, $p < .05$. The post-hoc tests revealed that preschoolers scored significantly lower than adults on species 2, species 3, and species 4; and school children scored significantly lower than adults on species 1, species 2, and species 4 (all ps $< .05$). There were no significant differences between the two groups of children.

Explicit responses

As in the previous experiments, participants' explicit verbal responses were coded using the scheme in Appendix D. As before, the experimenter coded the responses, and responses from 20% of participants were coded by another blind coder. Inter-rater reliability was 92% and differences were resolved by mutual discussion. Table 10 presents the mean proportions of the responses according to the different code category by age group.

Table 10: Mean proportions of utterances (and SDs) about novel animals summed across the four trial conditions for each age group

Agegroup	Total number	% size (a)	% prop. (b)	% prop. features (c)	% rel. features (d)	% other (e)
Preschool	5.5 (4.0)	92 (13.0)	0 (0.00)	0 (0.00)	3 (8.2)	5 (7.7)
School Age	16.6 (5.0)	54 (24.0)	0 (1.4)	20 (18.7)	8 (7.5)	17 (17.1)
Adult	9 (3.2)	55 (30.5)	3 (8.1)	20 (21.3)	4 (7.1)	13 (14.0)

Note: The second column (Total number) is the mean number of utterances; the rest are proportions. % size= expressions coded as indicating size changes; % prop.= expressions coded as head-body proportional changes; % prop. features= expressions coded as features that may indicate proportionality; % rel. features= expressions coded as relevant features; and % other= expressions coded as "irrelevant," "don't know," and "can't code." Columns a through e total 100, except 1% of school children's responses and 5% of adults' responses were coded as referring to the animals (on some stimuli) as identical.

A one-way analysis of variance on the total explicit verbal responses revealed a highly significant main effect of age, F (2, 27) = 18.1, p < .001. Post-hoc Tukey's tests showed that the older group of children were significantly different from both preschoolers and adults, both ps <

.001. Further analyses were done to show the differences between age groups on the different categories of responses:

a) As in the previous experiments, participants of different ages differed significantly in mentioning size as a factor contributing to growth, $F(2, 27) = 12.5$, $p < .001$. As expected from table 10 below, preschoolers made significantly more responses about size differences than the school children or adults, Tukey's post-hoc ps $< .001$.

b) Participants from different ages also differed significantly on their responses about proportionality, $F(2, 27) = 3.9$, $p < .05$, and about features that may contribute to proportional changes other than the head:body ratio, $F(2, 27) = 6.8$, $p < .001$. Post-hoc comparisons showed that adults made significantly more responses about features that indicate proportional differences than the preschool children, $p < .01$, but did not differ from school children. This is consistent with adults' responses in Experiment 1 with mammal species, albeit the effects were muted in this experiment with novel animals.

c) Participants from different age groups differed marginally in their responses that were categorized as other relevant features besides size and proportionality, $F(2, 27) = 3.3$, $p = .06$. School children differed from adults, $p = .05$, there were no further effects of age. Age was also not significant in the responses coded as "other" or the irrelevant category.

Discussion

This experiment was done to investigate the same questions about growth as in experiments 1 and 2, the only difference being pictures of novel animals were used as stimuli. In the absence of familiarity with the animals, our questions were: what do children and adults know about size changes, proportional changes during growth, and whether they weigh proportional changes over size changes when the two are in contrast to mammalian principles of growth.

As the results indicate, children and adults were almost at ceiling on the *no-conflict* control trials – they knew what the task involved and were able to use the principles of size and/or proportion to determine relative ages of the animals. This was true with the *megababy* trials as well – both groups of children were at ceiling on these trials, although adults were only slightly above chance. In the absence of biological concepts about these unfamiliar animals, participants from all ages seem to use size changes to determine growth. A change in size seems to be a robust indicator of growth and permeates species kinds. This is a well-learned lesson from real-life examples: all organisms that are alive grow by increasing in size including atypical animals such as sea-anemones, and plants. Adults, on the other hand, were similar to their counterparts in Experiments 1 and 2 in expecting a proportional difference. Adults seem to have an implicit *proportion* rule that is dominant, and adults over-generalize this rule to both reptiles and novel species.

On trials where size was not different for the two animals, as in the same-size trials, both groups of children were again chance responders, whereas adults were above chance. Children thus seem to be using the proportionality principle of selecting the animal with the larger head as younger, but only on some trials. Adults on the other hand were clearly attributing age changes to proportional changes.

These effects are robust: when proportion contrasts with size, adults continue to select the organism with the small head as older, even when that animal is pictorially smaller. That is, adults do not blindly select the smaller-depicted animal as younger, despite having a strong cue as size to indicate growth. Children, on the other hand, are swayed by size and predominantly select the smaller organisms as younger.

These results are confirmed by participants' explicit responses: 92% of preschoolers' verbal remarks are about size changes, and nearly 50% of the remarks of the other groups are also about size changes. However, adults made significantly more remarks about proportionality than younger children. Thus all participants clearly knew the importance of size; in addition, adults seem to realize that proportional differences are important indicators of growth across different animal species. This is the first study to report such findings. It must be noted that the adults who participated in this study were college students who did not major in biology, i.e., novices when it comes to understanding growth principles in animals. Finally, although the stimuli depicted made-up, unfamiliar, alien animals, participants could have induced familiarity between these creatures and animals in the real world. We were careful in removing any appendage that was reminiscent of features present in real animals, and substituted bizarre antennae, or stalk-like limbs. The children readily accepted these animals as alien animals, and willingly entered into finding which the baby and "grown-up" animals were. We believe these findings are generalizable to the lay public that has some knowledge about animals, and growth related changes in animals.

CHAPTER V

GENERAL DISCUSSION

What do children and adults know about growth in different animals?

A complex picture emerges from our three experiments on children and adults' concepts about growth in a variety of animal species. Young children understand size changes as fundamental to growth, and proportional changes are part of their repertoire of growth concepts from an early age, although these concepts have some limitations. Older children and adults are more sophisticated in their inductions about biological growth, and expect proportional changes even in the light of contradicting size changes. However these results cannot be considered without looking at the evidence from all three studies together.

The present study

Three experiments were conducted to find out what 4-5-year-old children, 8-10-year-old children and adults know about principles of physical growth of animals. The animals included exemplars of three orders of mammals (Primates, Carnivores, and Artiodactyls) and three orders of reptiles (Reptilia, Squamata, and Testudines), and a sample of animals from "imaginary" orders. The experiments were designed to learn about participants' "implicit knowledge" and "explicit knowledge." By implicit knowledge we mean information that is revealed by participants' use of rules governing growth, for example the size and proportion rules, on the judgment task. By explicit knowledge we mean the rules about growth that participants verbally stated. The experiments were designed to probe participants' implicit and explicit knowledge of two principles that govern physical growth of animals: the “size rule” according to which animals become larger (in stature) as they grow, and the “proportion rule” according to which some animals show a progression from having a larger head-to-body proportion to having a smaller head-to-body proportion.

In Experiment 1, we looked at children and adults’ understanding of growth in mammals. All participants evinced their knowledge of the size rule, both implicitly and explicitly. Preschoolers and older children showed some implicit understanding of the proportion rule, but no explicit knowledge. Adults showed both an implicit and explicit understanding of the proportion rule.

In Experiment 2, we looked at children’s and adults’ understanding of growth in reptiles. All participants showed both implicit and explicit understanding of the size rule. Preschoolers and some school children showed no implicit knowledge of the proportion rule, but adults judged by proportion on some trials. Adults and some older children evinced some explicit knowledge about proportion.

In Experiment 3, we looked at children and adults’ understanding of growth in imaginary, novel animals. All participants used the size rule both implicitly and explicitly as in the first two experiments. As before preschoolers and school children showed no implicit knowledge of the proportion rule, although adults did. Adults and older children also demonstrated some explicit knowledge about proportion but younger children did not.

The remainder of this general discussion summarizes what rules the children of each age group and adults used for their implicit and explicit judgments. I continue by speculating about what processes might account for the age-related changes. And finally, I discuss some implications of the findings for education.

Preschool children's concepts

In the introduction, we began with questions about whether preschool children understand that size changes with growth in different animal species, whether they understand that proportional changes accompany growth in some species and not others, and whether they would weigh proportional changes as more intrinsic to growth than size changes. The first experiment provided evidence that young children do understand the importance of size changes in familiar mammals, that they also understand different head-body ratios distinguish different ages, but that their understanding of proportionality is secondary to size changes. Figure 1 gives an idea of preschoolers' performance on the three experiments with mammals, reptiles and novel species.

If we take preschoolers' concepts about mammals as a baseline (i.e., on the assumption that they are most familiar with mammals), their concepts about reptiles and growth in general seem to be centered on size changes. They are at ceiling on the no-conflict and mega-baby trials, readily accepting that bigger animals are older and smaller are younger. Previous studies that have tested for preschoolers understanding of growth have mainly presented them with variance in size (Danziger & Smith, 1958; Hatano et al., 1993; Rosengren et al., 1991; Stavy & Wax, 1983) and elicited concepts of growth based on size. Concepts about the importance of size are so entrenched with preschoolers that they go to the extreme of ignoring proportionality information in the conflict trials across all species in the present investigation.

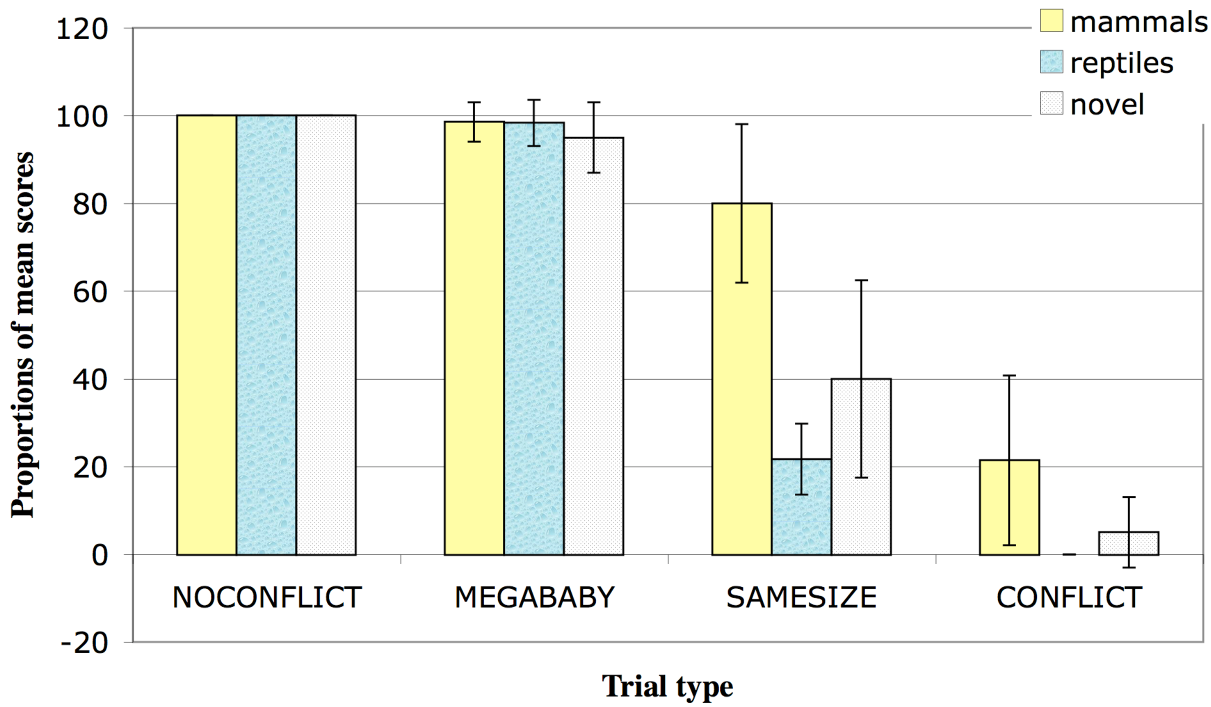


Figure 1: Preschoolers' mean scores (and SDs) in Experiments 1, 2, and 3

This is interesting, especially when we consider the evidence that preschoolers are not ignorant about proportionality: they are above chance on the same-size trials with mammals, where size changes are not depicted. The only other study we know that looked at proportional changes in children is by Dehart et al., (in preparation), where the experimenters found that children selected the picture of an animal that was proportioned like a mammalian adult, as the parent of another animal that resembled a mammalian baby. It must be noted that even our youngest children selected by proportion on the *conflict* trials with the *human* baby and *human* adult pictures. Again this can be expected due to familiarity with human babies and adult caregivers, and conforms to earlier findings (e.g., Nash, 1973). This is an extension of the idea of "cuteness" that have been studied by many researchers: Judith Langlois and colleagues, for example, showed that people think that animals with large head-to-body proportions, rounded facial contours, and eyes below the facial midline are cute. Such features are probably evolutionarily advantageous--parent animals, including human caregivers are attracted to "cute" animals. Pittenger (1990) found that books for children that depict animals have capitalized on this feature of proportionality—they depict reptiles, and animals from other classes with large heads and rounded faces.

However in our studies with reptiles and novel species, when information about size is not available, preschoolers seem to resort to size changes in particular body parts. For example, with reptiles, most preschoolers seem to indicate that the animal with the bigger head is the older animal in the same size trials. With the novel species, preschoolers seem equivocal in selecting head size to represent age.

Preschoolers' explicit knowledge reflects this general trend: a large portion of their responses about why they thought a particular animal was a baby or grown-up was based on size differences. Keil (1983) found that 3-year-old children associated the verb "grow" with an increase in size in animals and plants. Adult caregivers use the word "grow" in this sense of referring to size changes (Gelman et al., 1998). Although preschoolers seem to implicitly understand that different head-body ratios indicate growth, they do not seem to know to articulate these thoughts. This was particularly evident when one child was presented with the conflict trial where the pictures depicted a small human adult, and a large human baby. He correctly identified the small human as the "grown up" and the large picture as the "baby." When the experimenter asked him why he thought the small picture was the grown-up, the child said, "Oh, she [the human in the picture] just *looks* smaller 'cos she's standing far away."

School-age children's concepts

By the time children are in third grade, they have acquired extensive information about animal kinds through school activities and the media. The reason we investigated school children's concepts about biological growth was to obtain some evidence as to the nature of older children's concepts, and whether these concepts are different from preschoolers' concepts and adults' theories—to answer the question what changes with development. Figure 2 gives older children's scores on the three experiments across different trial types.

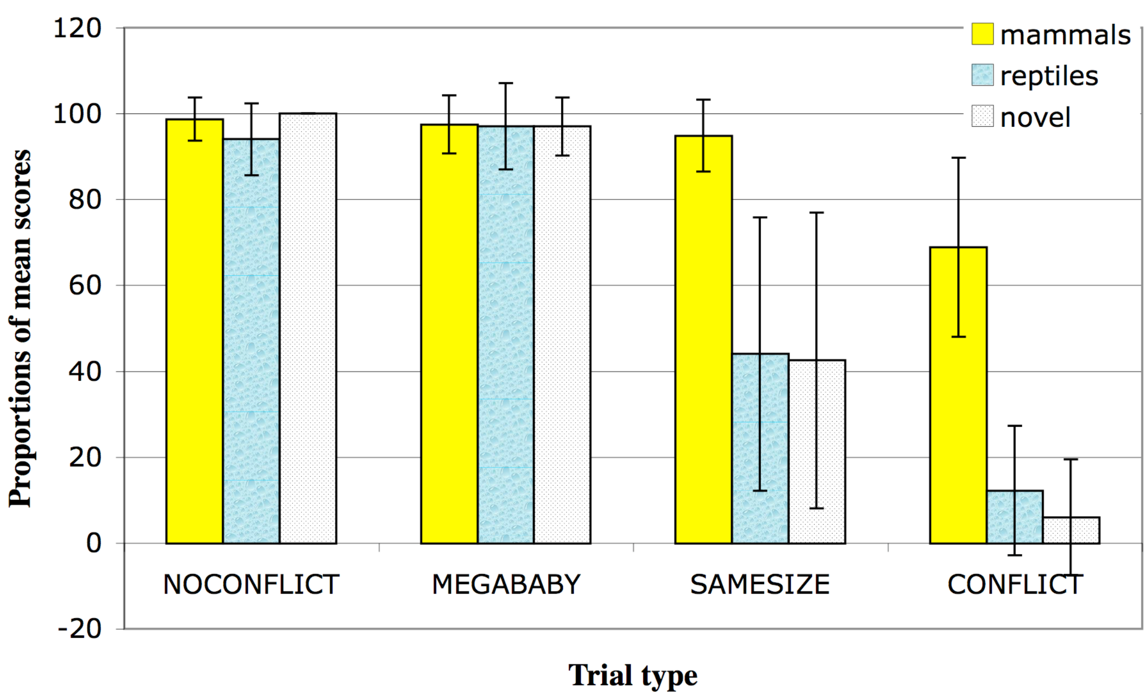


Figure 2: School-age children's mean scores (and SDs) in Experiments 1, 2, and 3

As with the preschoolers, school children are at ceiling with the no-conflict and mega-baby trials acknowledging size change as an important indicator of growth. They depart from preschoolers' thinking on the same-size and no-conflict trials with mammals: they judge the animal that has a smaller head-body proportion as older, and the animal with the larger head-smaller body as younger. Their responses on these trials with mammal species are well above chance levels. This is unsurprising: school children are more informed, not just about familiar mammals. The school curriculum includes lessons about the life-cycles of many animals and plants from kindergarten through fourth grade. Besides, most children are also aware of the arithmetic concepts of ratios and proportionality, albeit not an awareness of growth as proportional changes.

What is interesting, however, is their *apparent unawareness* about proportional changes in reptiles: apparent because reptiles really do not show proportional changes. Some third graders were above chance with the same-size trials, using the mammalian proportionality principle to judge age. This is evidence of mature reasoning: younger vertebrates generally have larger heads and smaller bodies. Shaw, Pittenger and colleagues (see Mark et al., 1986, 1988) have shown that adult subjects judge this cranioidal progression (i.e., from having larger head-body proportions to smaller head-body proportions) with remote objects such as a robot, a Martian, and a flower as growth. School children probably have induced this relationship from the real-life examples that abound. Other children responded akin to preschoolers, and selected the animal with the large head-small body as older. They could have used absolute size (e.g., large head) instead of relative size to judge age. While school children seem to be reasoning more like adults than preschoolers, they reveal some gaps in their knowledge about growth. Tamir et al. (1981) found that some fourth graders thought that the pupa, an intermediary stage in insect metamorphosis, was "not alive," a misconception that persisted even after practical experience with insect life-cycles. Alternatively, their responses could have resulted from confusion as to which of two animals that do not seem to belong to the same species could really be the older, a rather sophisticated line of reasoning. There is reason to believe the former, however: on the *conflict* trials with reptiles, third-graders including those who used the proportionality principle on the same-size trials, selected the smaller animal (with small head-large body) as *younger*. Further, on the same-size trials with the novel, unfamiliar animals, most third-graders were at or below chance levels in selecting the animal with the larger head as the baby. On conflict trials with the novel animals third-graders were below chance levels. Thus they revert to using size as the default principle by which to judge age.

School children articulated more than preschoolers in some instances, and more than adults in other instances. Their responses were also more differentiated than the preschoolers' responses. Whereas the younger children talked mainly about size differences, school children revealed their knowledge about features other than head-body proportional differences, but which were related to proportionality, such as larger eyes or rounded contours in the baby animals. Third-graders also remarked about features such as droopy ears, longer tails, or the presence of wrinkles that were present in the pictures and could have provided cues to age. These remarks were different from the other age groups: preschoolers probably did not notice these differences or were unable to articulate their thoughts about these features, and adults simply might have concentrated on the deeper proportionality features and considered these as superficial and irrelevant.

So what do adults know about growth?

Although the psychology and anthropology literatures abound in studies of adults' folk knowledge of animals, plants, and the taxonomical structure of major categories of living things, the paucity of studies looking at what adults know about growth persuaded us to include adults as subjects in these studies. Adults have far greater knowledge than children about animals, and the necessary vocabulary to articulate their thoughts. However, we did uncover some interesting findings. Figure 3 presents a summary of their scores on the different trial types across experiments.

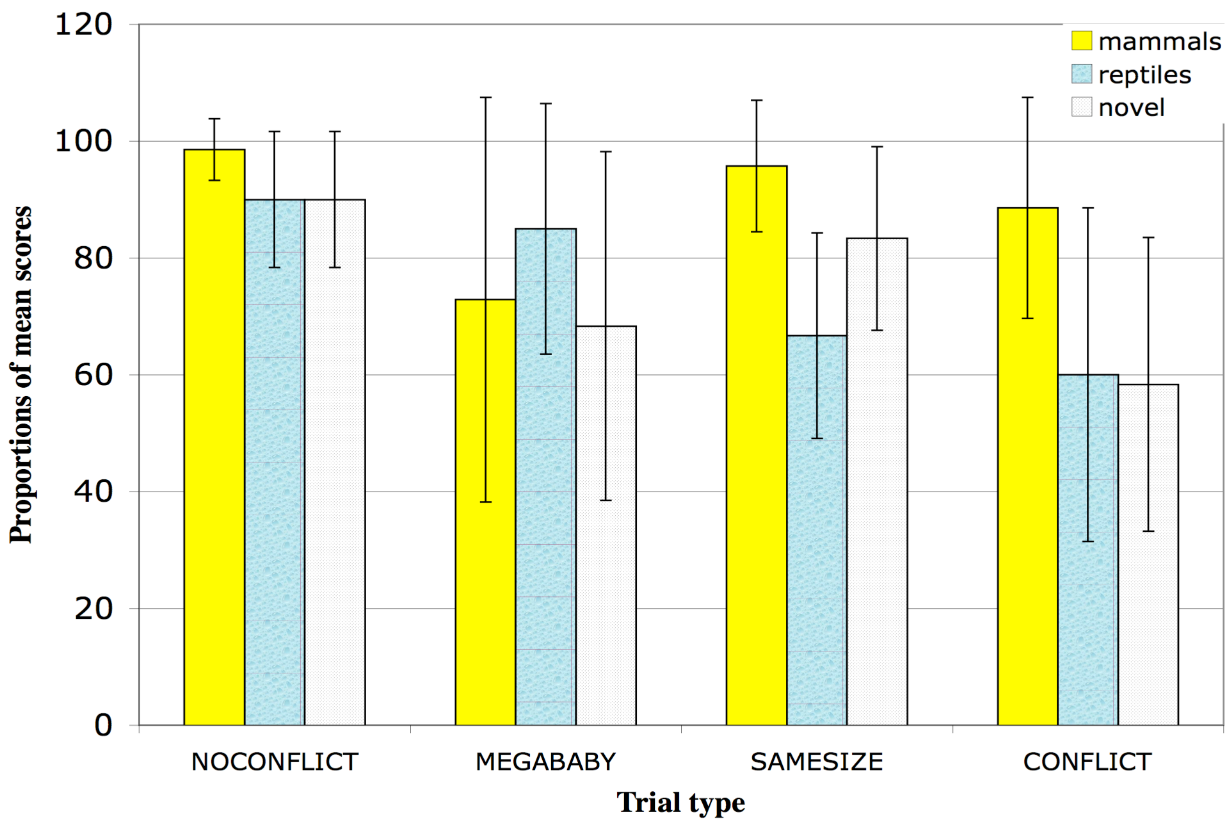


Figure 3: Adults' mean scores (and SDs) in Experiments 1, 2, and 3

As expected adults easily selected the appropriate animals based on size differences in the no-conflict trials across all species. A few adults confused the pictures of small-baby and large-older animal on these trials with the large-baby and small-older animal on the conflict trials: their expectations lead them to pick the small baby on some no-conflict trials as the older animal. Apart from these minor deviations they showed an understanding that size change was an important factor of growth. A considerable portion of their explicit responses was about size changes (although see below).

Adults also displayed a far stronger sense of proportionality then either groups of children. On the mega-baby trials with mammals, several adults initially refused to select one or the other as the older animal, merely because (they said) the two animals looked the same, and one ought to "look" different. With reptiles, adults did not seem to have as much difficulty in selecting one animal as younger and the other as older, but with novel species their responses were not different from chance levels. This could be taken as indirect evidence that adults are aware that proportional differences, while being important to mammalian growth, may not be the norm with reptiles. On the other hand, adults seem to expect proportionality as a general indicator of age differences—their performance with the novel animal species.

The same-size and conflict trials with mammal pictures posed no problems: adults selected primarily based on proportion on these trials, and were close to the maximum score possible. On the other hand, their scores were not different from chance on the same-size and conflict trials with other animal species, with the one exception of same-size trials with novel animals. On these trials with unfamiliar animals, their selections were based primarily on proportionality. Thus adults' expectation of proportionality as intrinsic to growth is a generalized expectation, one that permeates the boundaries of class structure of the species. This has been found in earlier studies by Pittenger, Shaw and colleagues mentioned above: adults understand this process of change from having a big head and small torso to having a smaller head-to-body proportion, as growth, when presented with pictures at both extremes. Adults in the studies mentioned above granted this type of change to objects alien to such processes: a robot, a Martian, and even a flower.

Finally, adults are facile at expressing ideas about proportionality, although this was best revealed with mammals: 37% of all of their explicit observations were about proportionality, much higher than any other group we tested. They did not articulate as much about proportionality with the other animal species as with mammals, again some evidence that adults may be aware that proportional differences are “unnatural” with certain species.

Overall, children seem to have a nested concept of growth such as “Use size changes as indicating growth. When size information cannot be reliably discerned, then use proportion rule but only with mammals. For other species, use “head size” or muddle through.” School children seem to have the rudiments of proportionality as a general principle, but adults have a strong sense of proportionality. Thus the older groups might have a nested rule like this: “Use proportion with mammals and other familiar species. Use size, but only when proportion is not a reliable indicator of growth, and only for animals that don’t look like mammals or other familiar species.”

Conclusions and future directions

The studies we have conducted reveal that preschoolers have a fundamental understanding of the importance of size changes in growth, which is in agreement with previous studies. However, preschoolers exhibit knowledge of proportionality with some animals, especially mammalian species that are familiar to them. They do not seem to indicate conclusively that proportionality does or does not matter with other species. Further preschooler children do not articulate the proportional differences they noticed with mammal species.

Future studies should investigate whether making the task easier and more informative (for example, use pictures of human babies and adults or use photographs instead of line-drawings) might enable preschoolers to express proportionality implicitly and explicitly. The preschoolers tested in this study were 4 years or older. Preschool children may know about proportional differences at an earlier age, implicating another set of studies in the future. Growth is a dynamic process. Perhaps modeling growth using simple animation techniques provides a more realistic scenario of the changes that take place during growth. Animation about gait, movement, and postural changes that provide cues about age can also be studied. Finally studies investigating children from different cultural background are needed to obtain a more complete picture of growth related concepts.

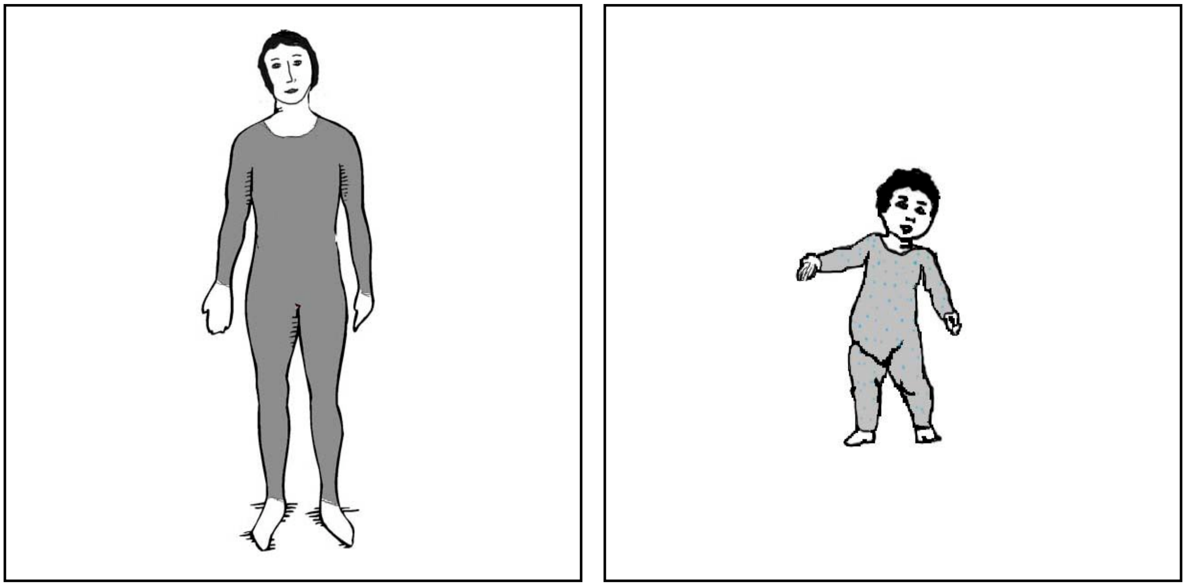
School children reveal a better understanding of proportionality than did the preschoolers and were able to articulate their thoughts in a few instances. Perhaps richer stimuli, or animation might help them. The effect of classroom instruction looking at life-cycles of familiar organisms need to be studied, in a more immediate setting. Adults are more aware about proportionality than either groups of children, but it would be interesting to find out what adults in non-industrialized cultures think about proportionality in growth, and whether they would even talk about growth in the same ways that we do.

APPENDICES

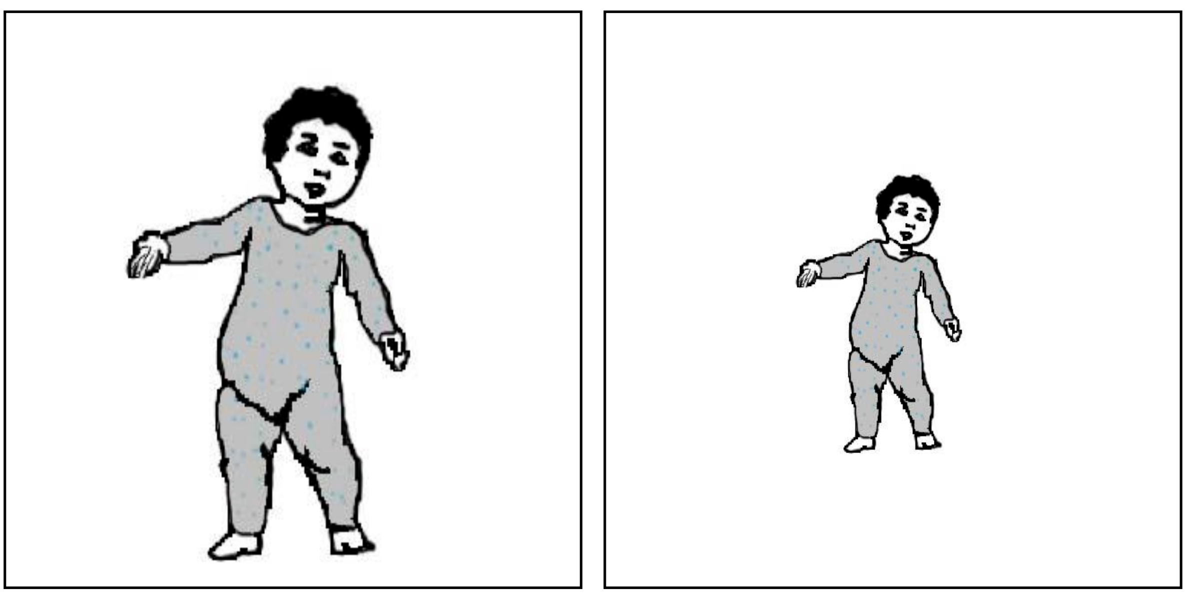
Appendix A

Sets of pictures from mammal species used in Experiment I

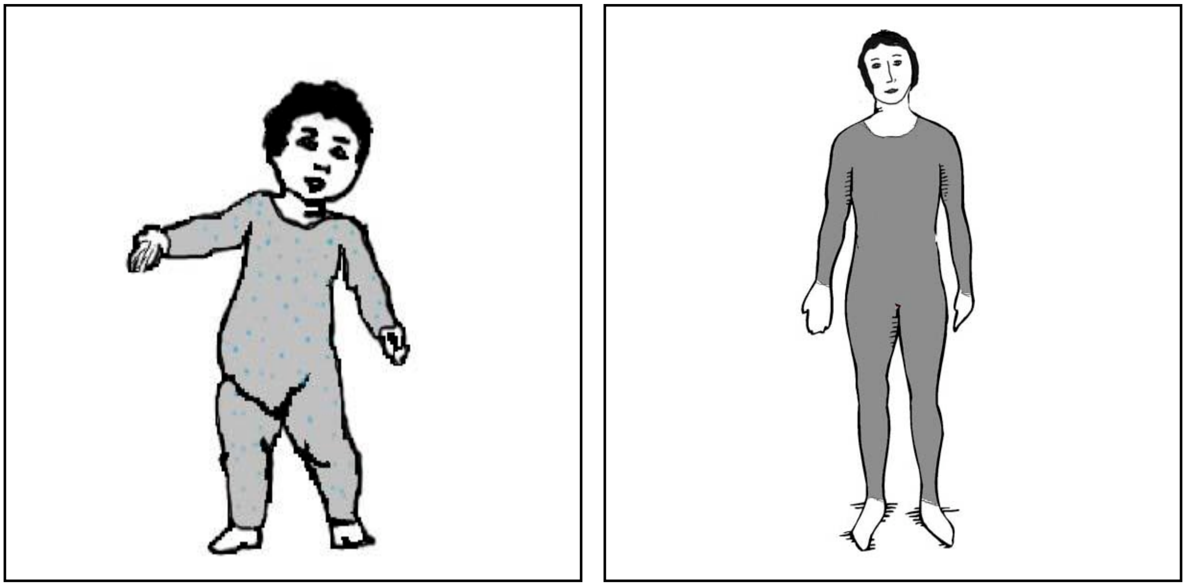
HUMAN
No- Conflict



Mega-baby



HUMAN (contd.)
Same-size



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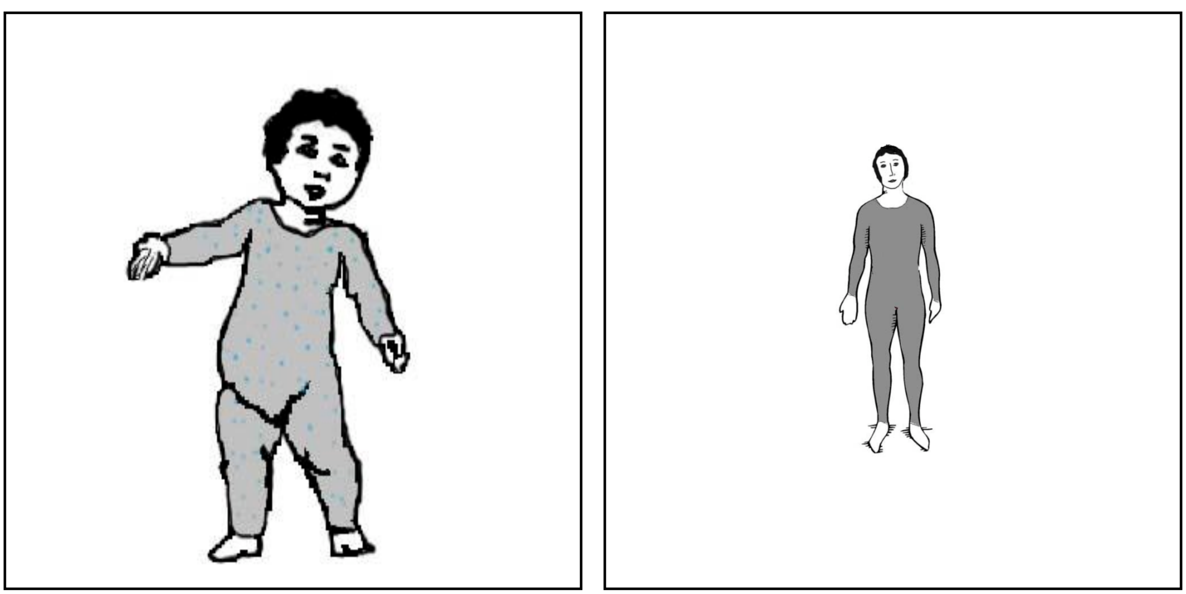

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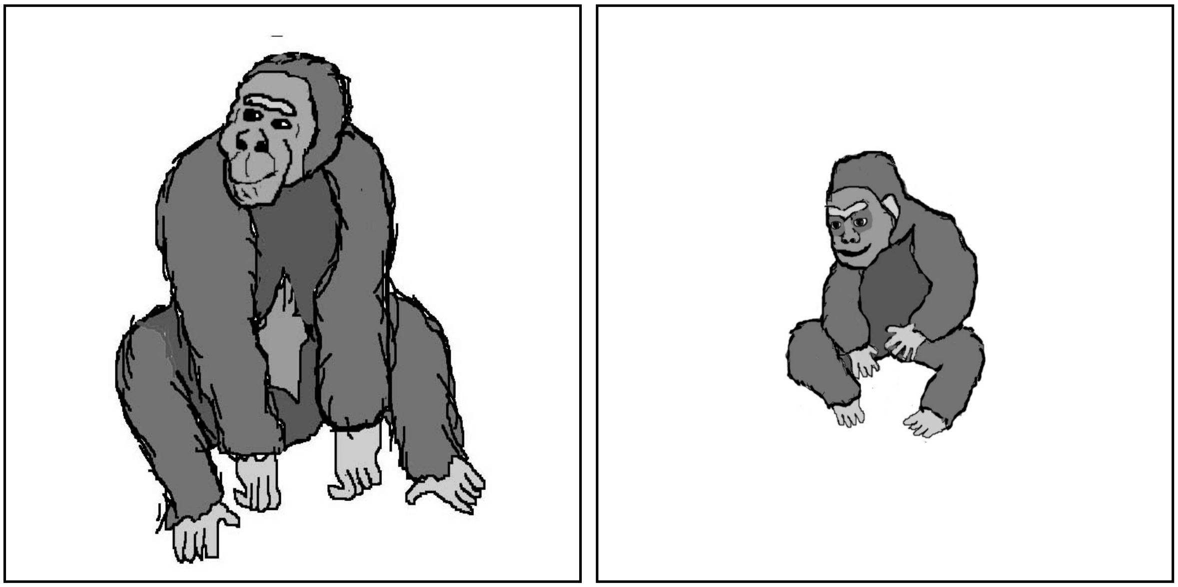
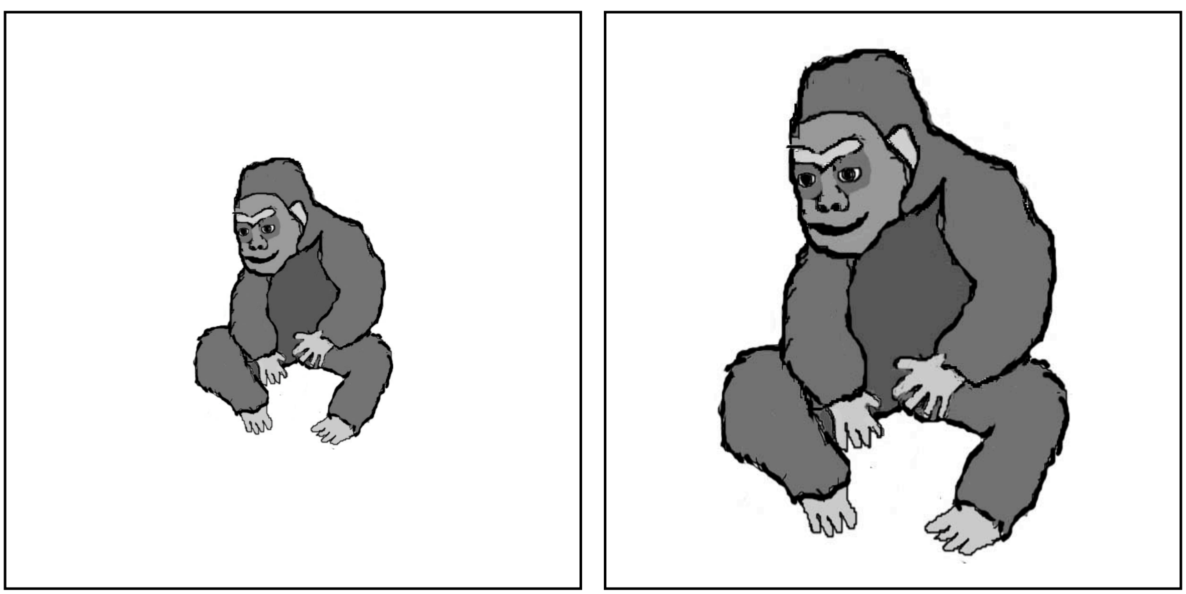
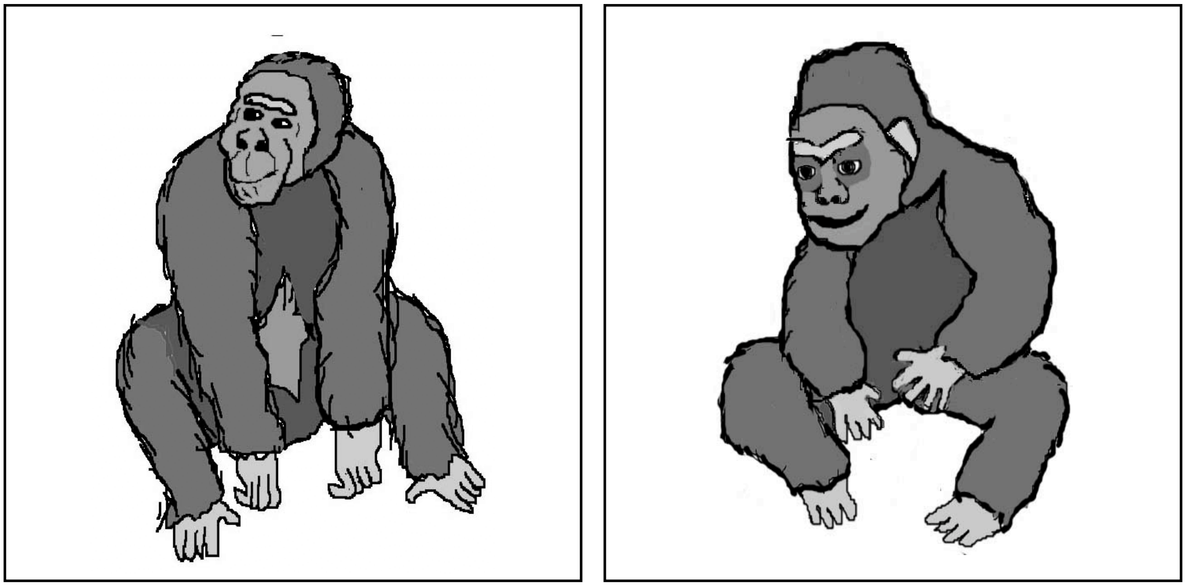


Mega-baby

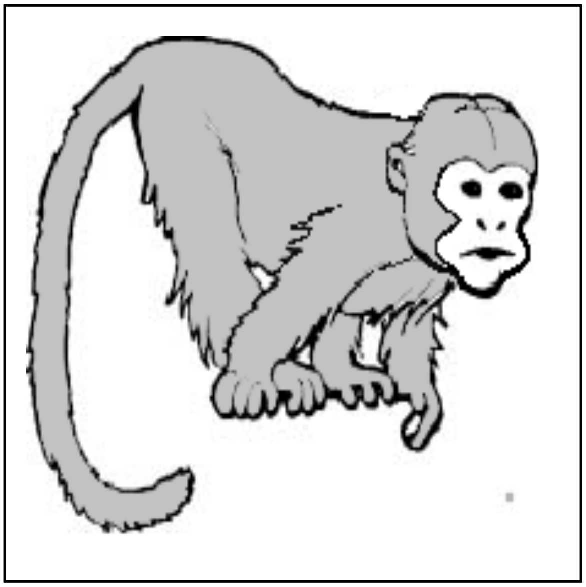


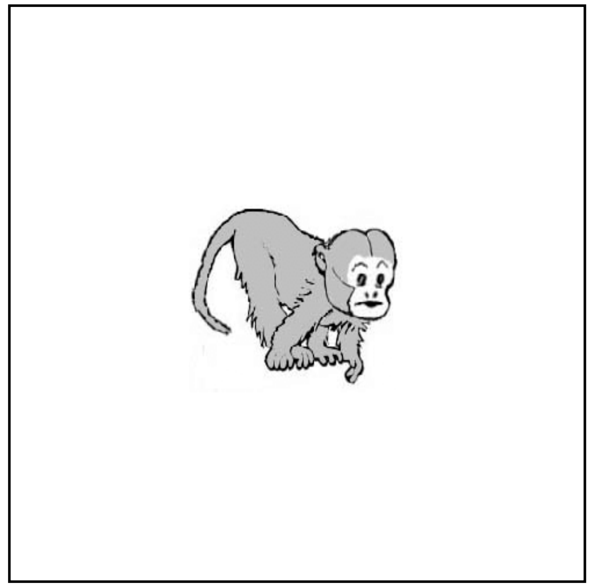
GORILLA (contd.)
Same-size



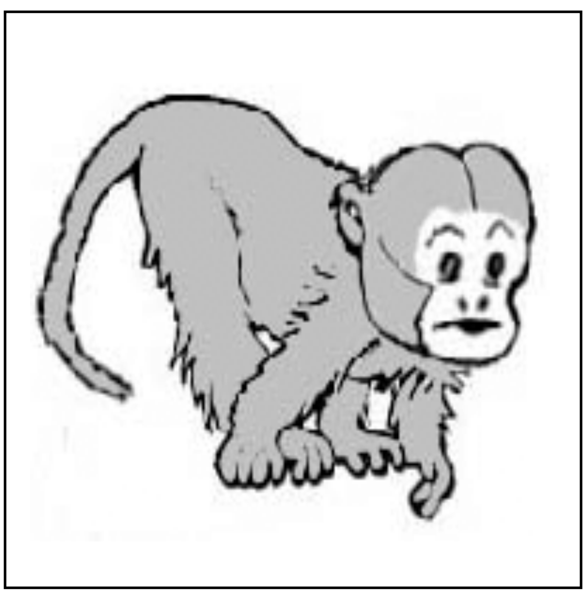
Conflict

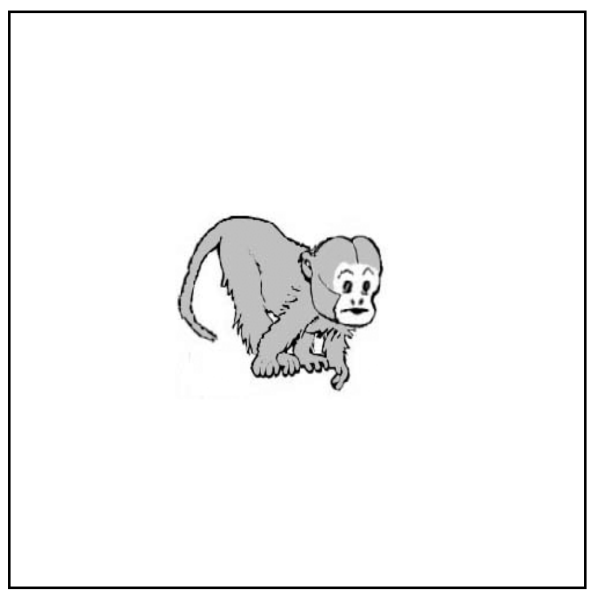
MONKEY
No Conflict





Mega-baby





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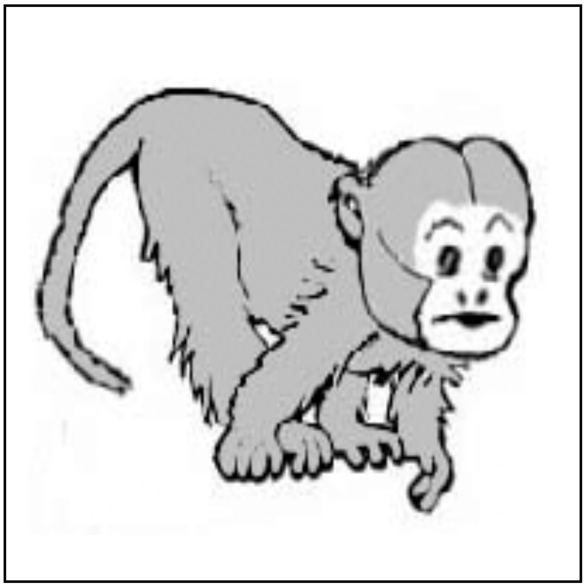

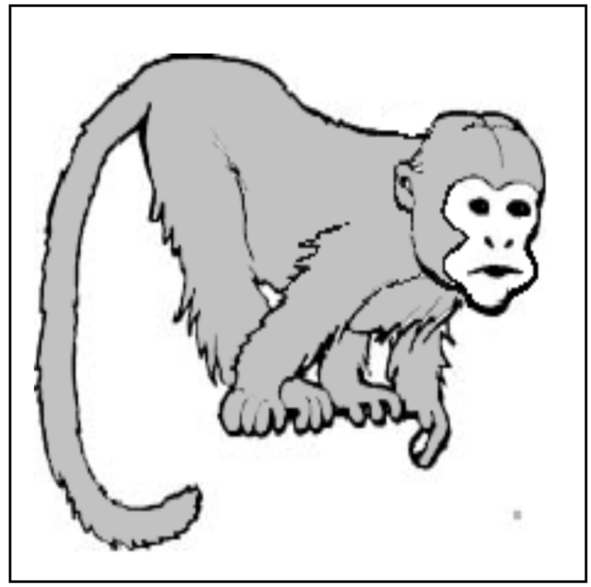

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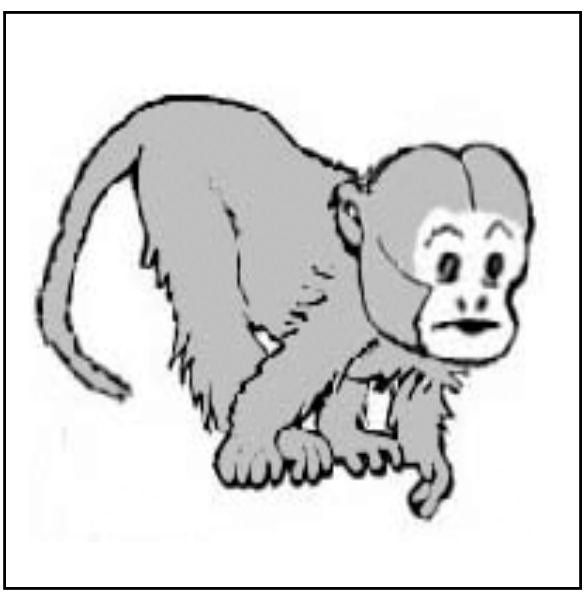

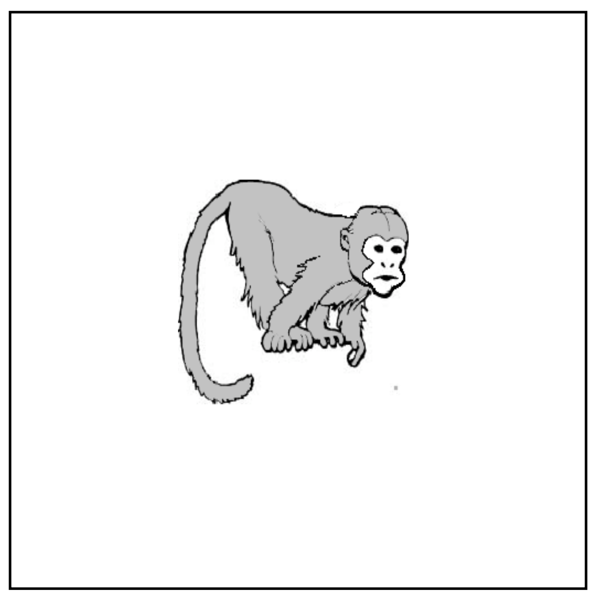

DOG
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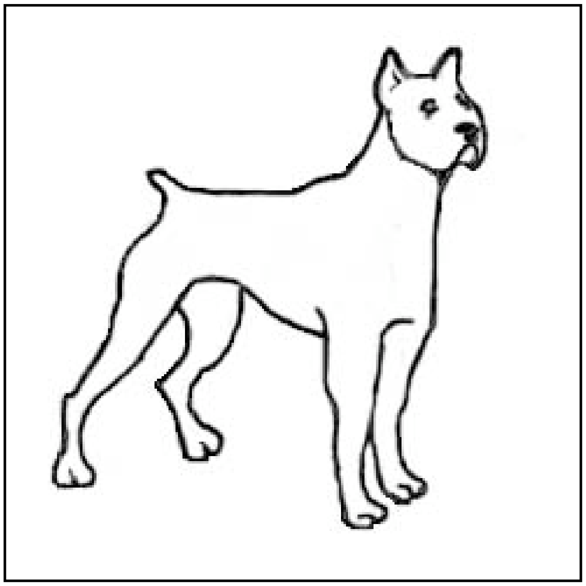

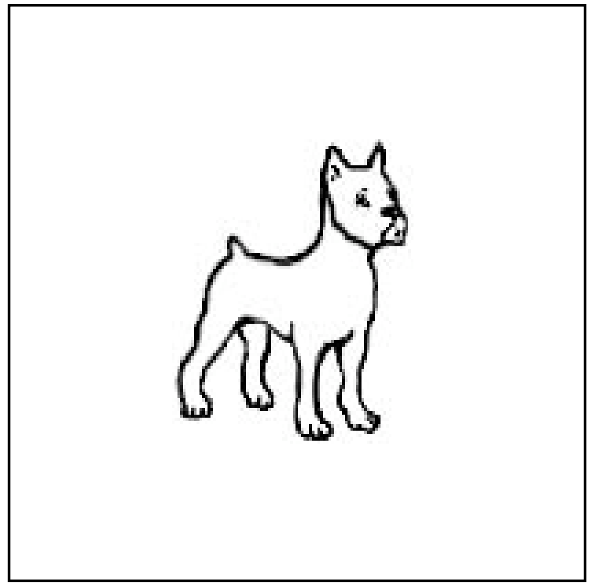

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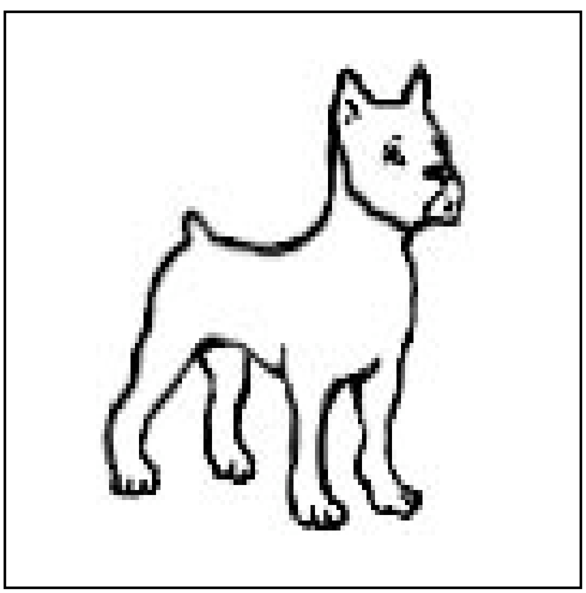

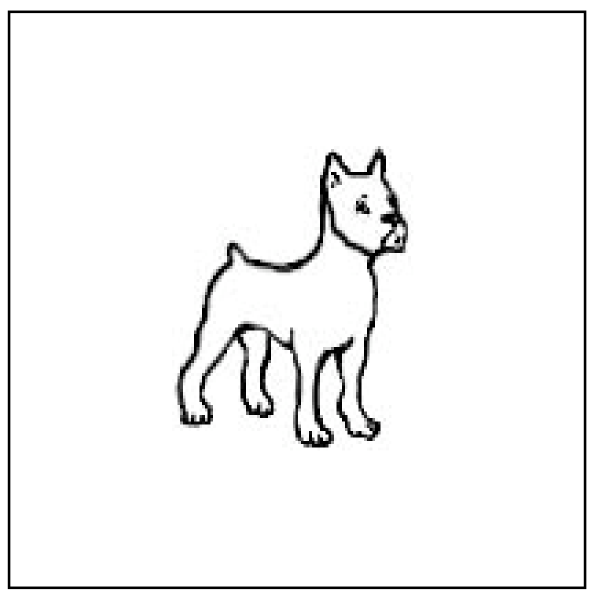

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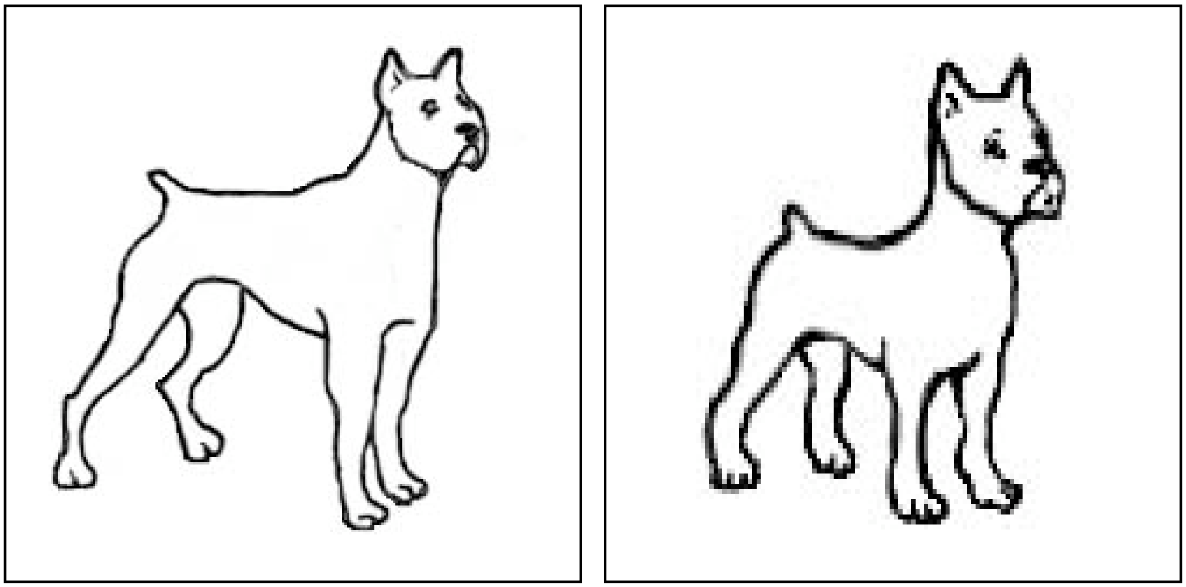
Same-size



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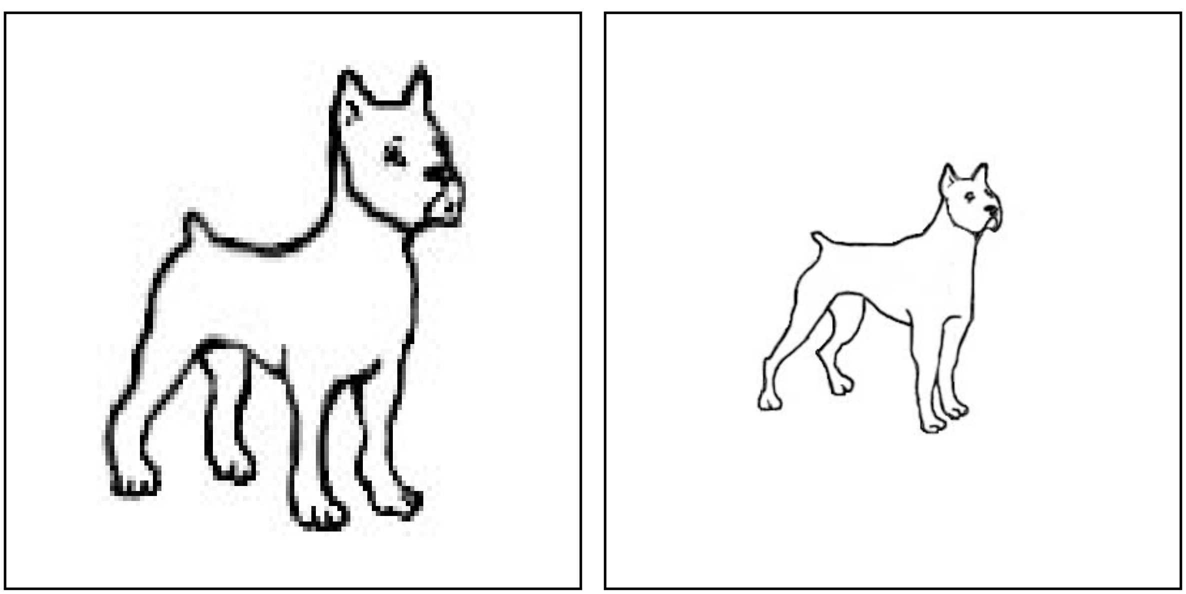

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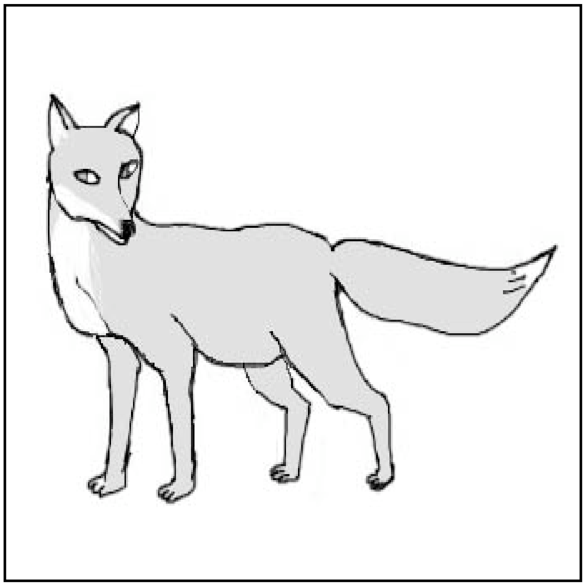

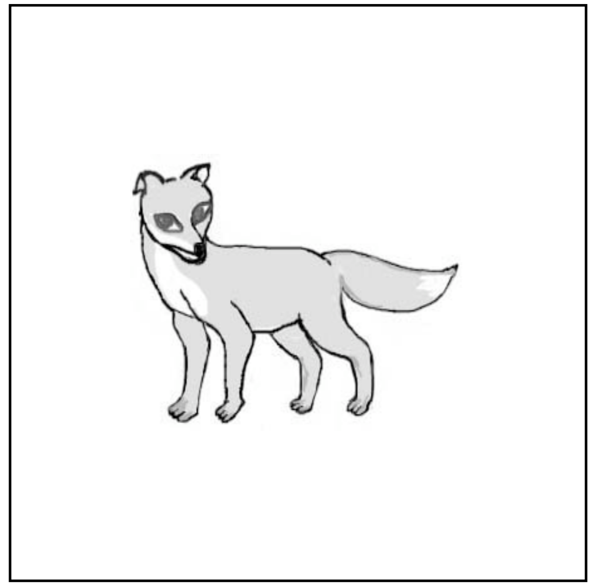

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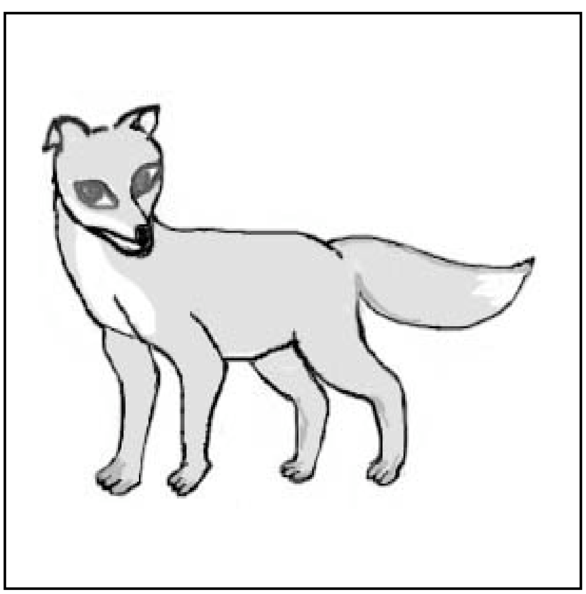

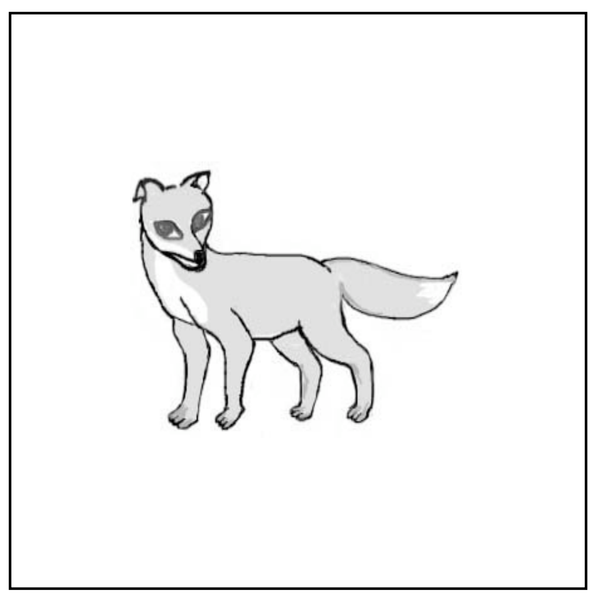

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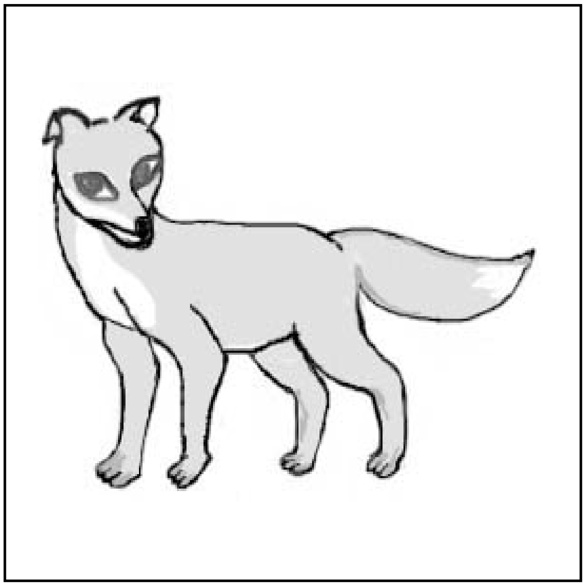
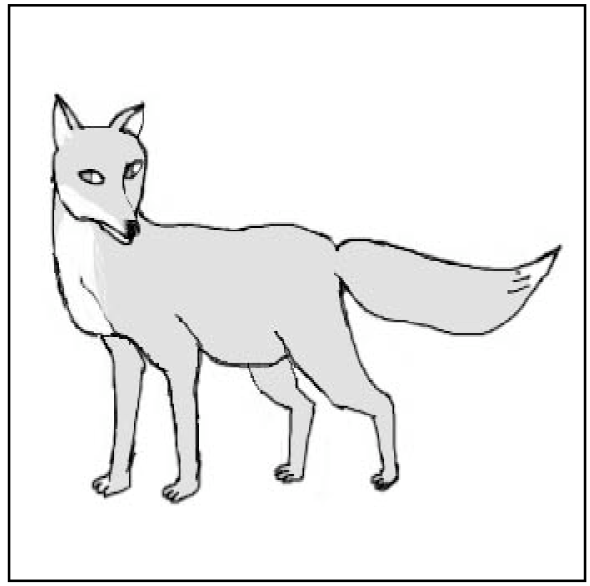

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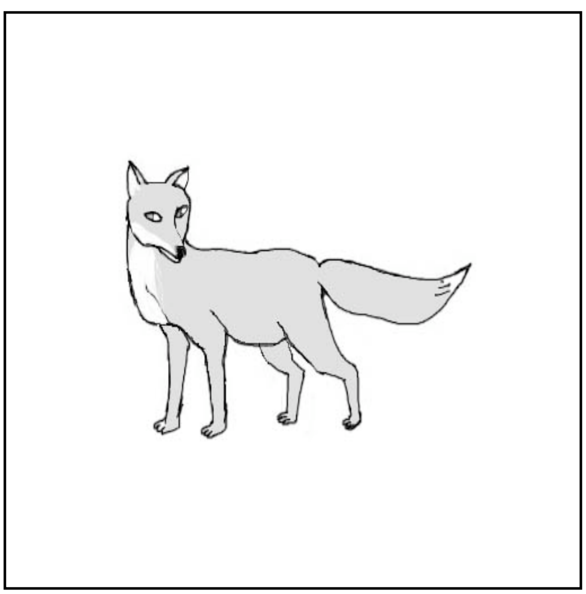
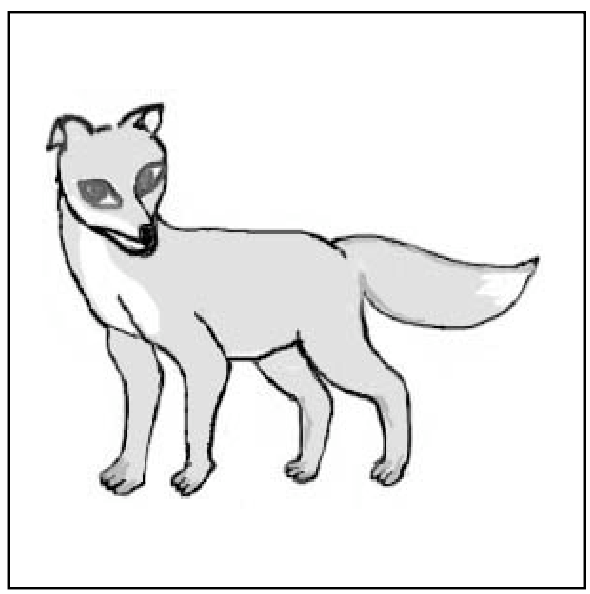

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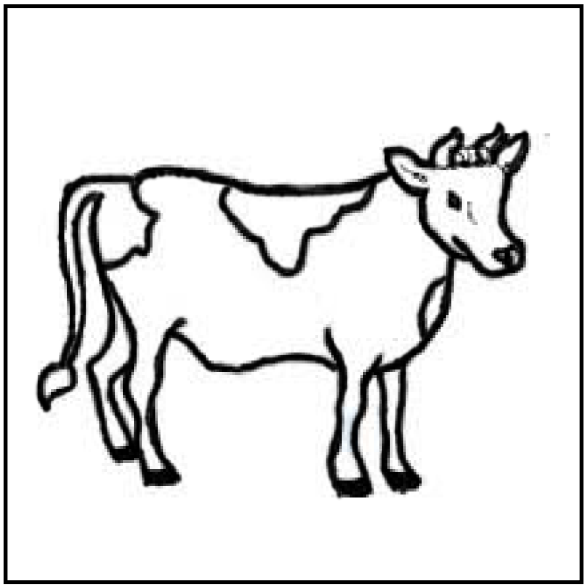
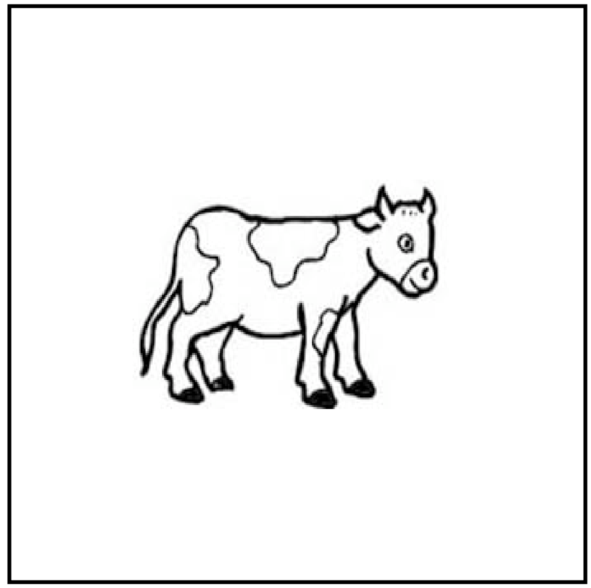
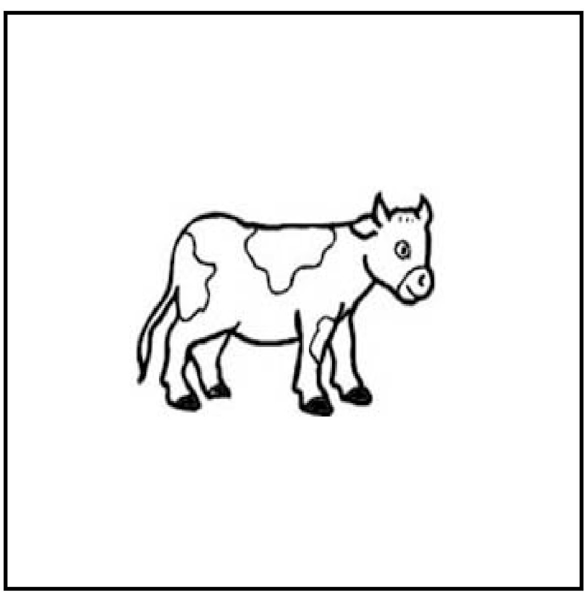
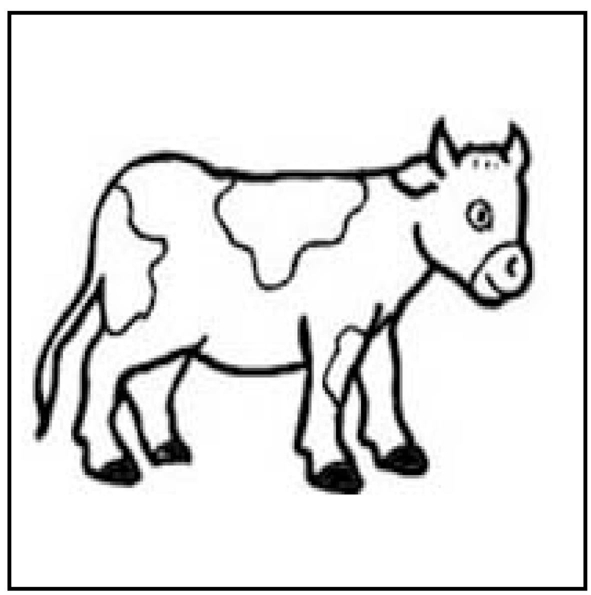




Mega-baby





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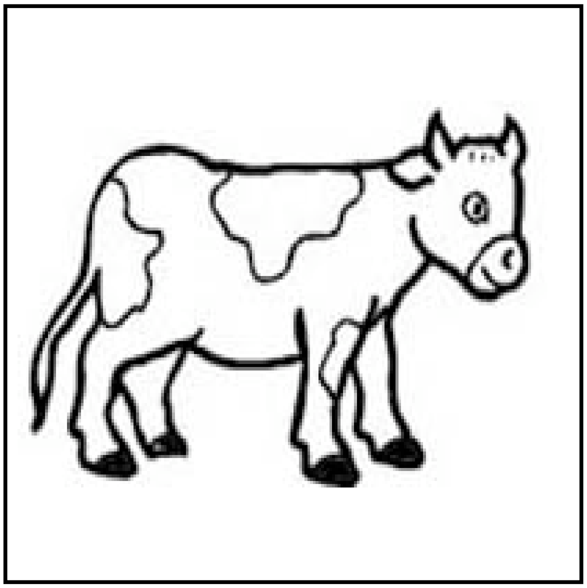
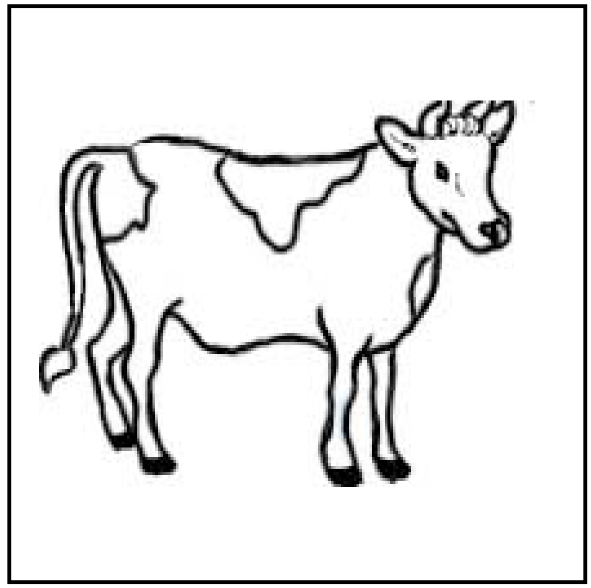

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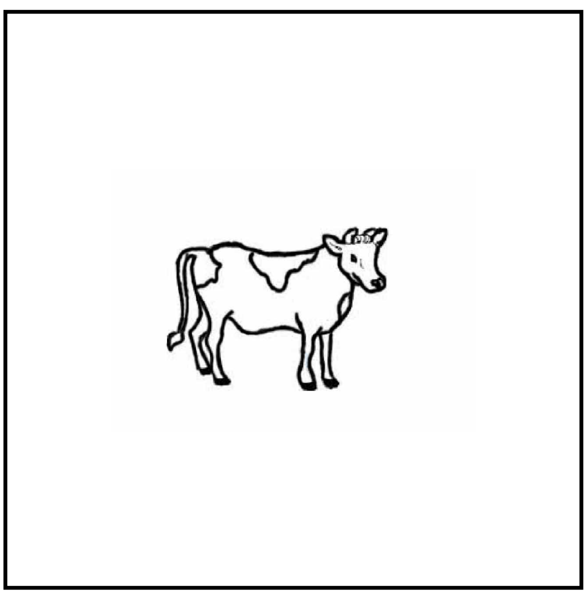
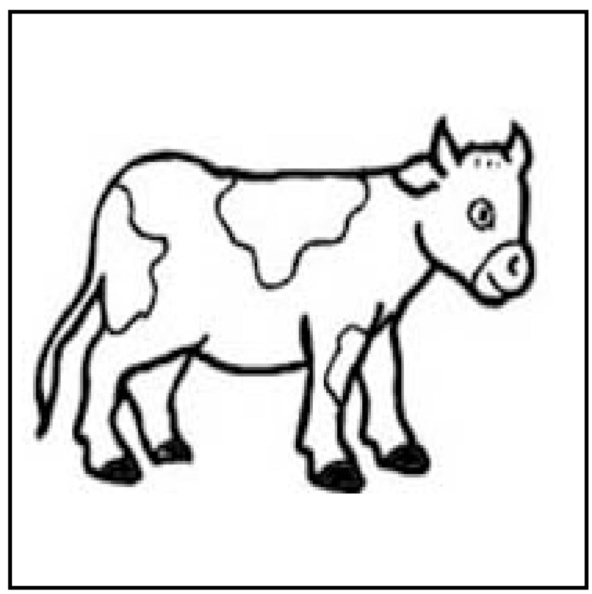

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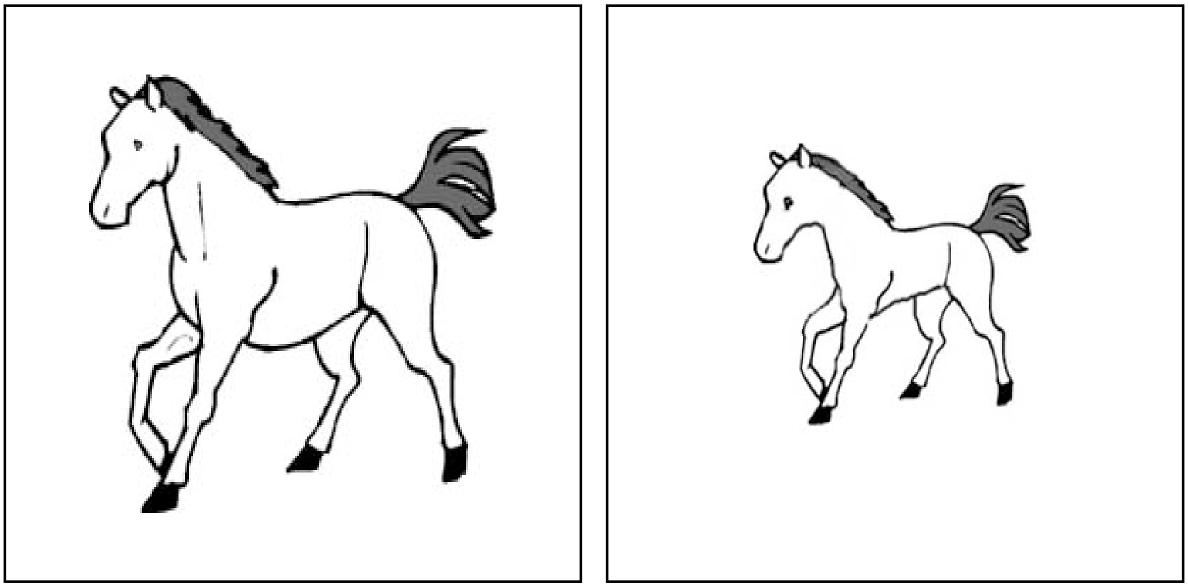
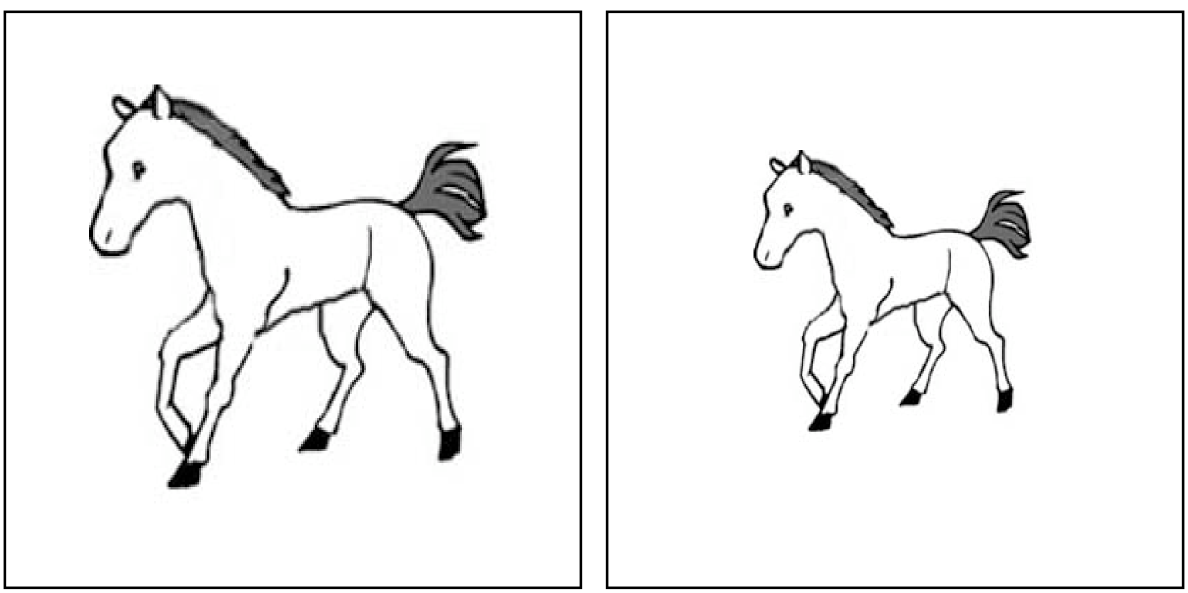


Mega-baby



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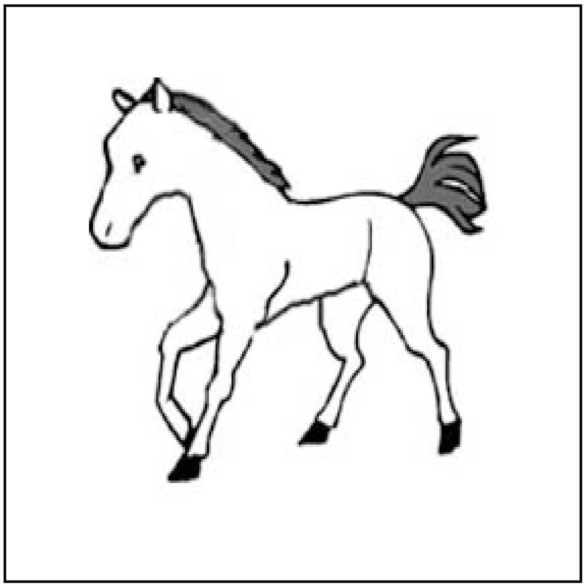

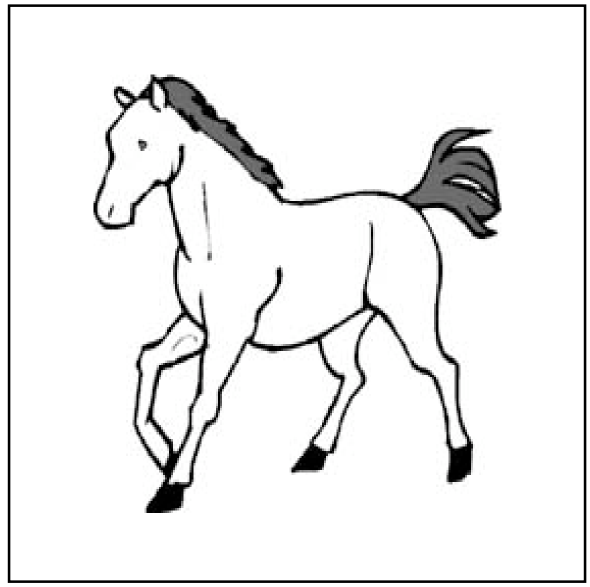

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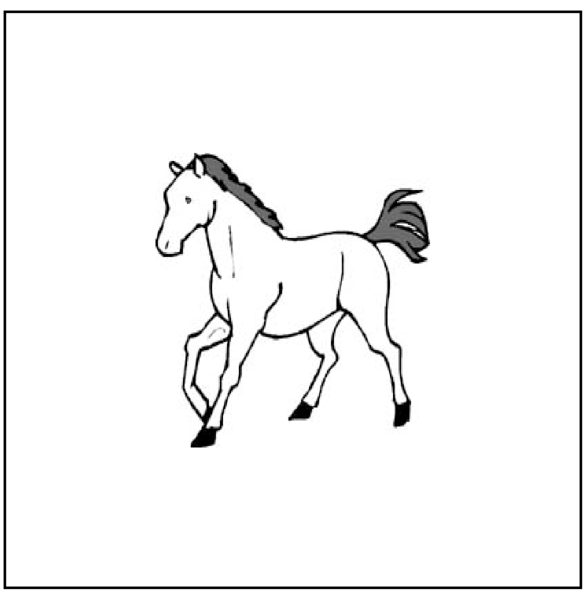
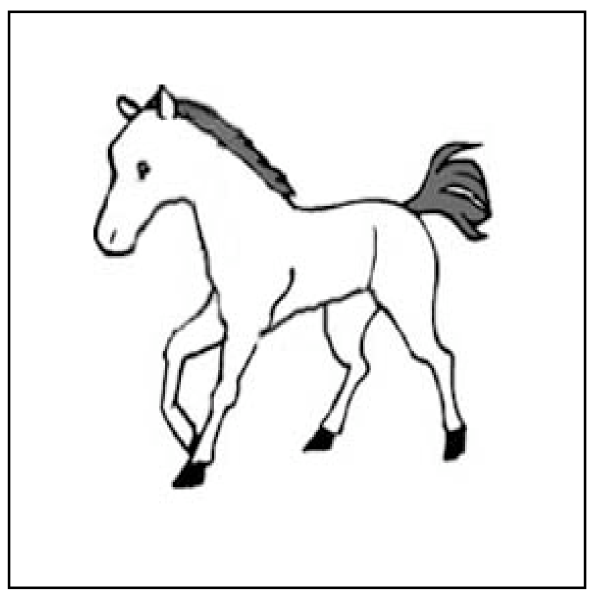
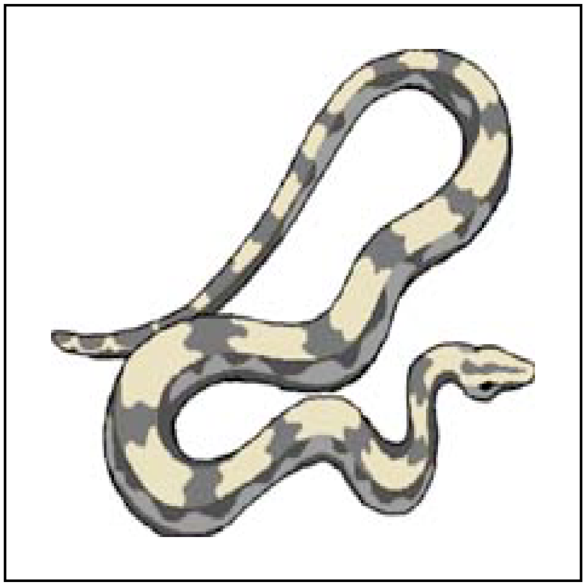


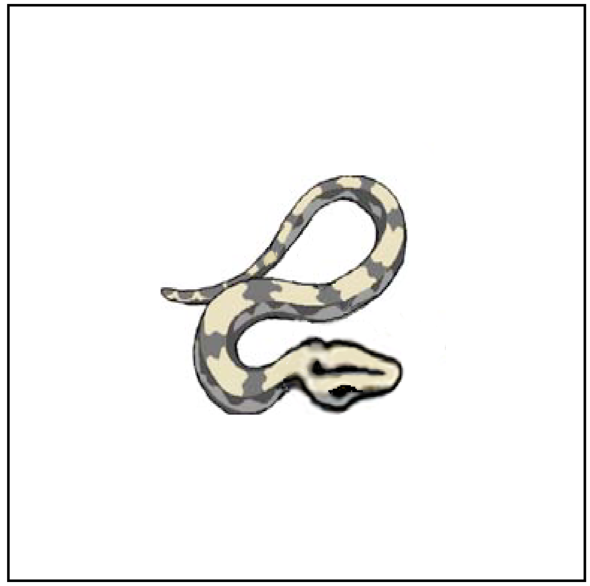


Appendix B

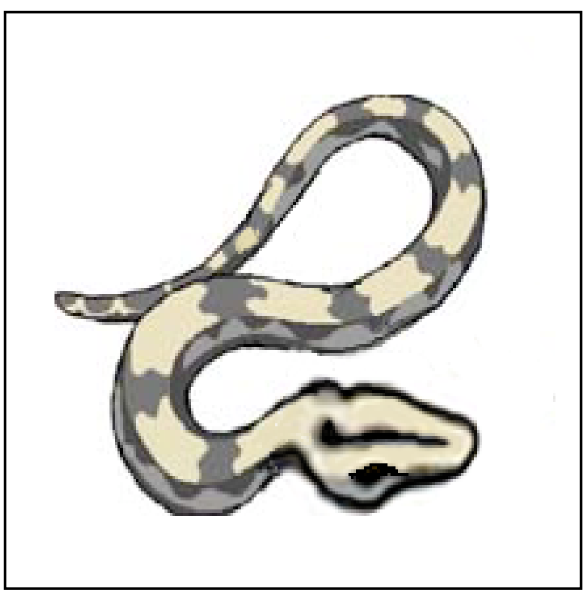
Sets of pictures from reptile species used in Experiment II

PYTHON
No Conflict

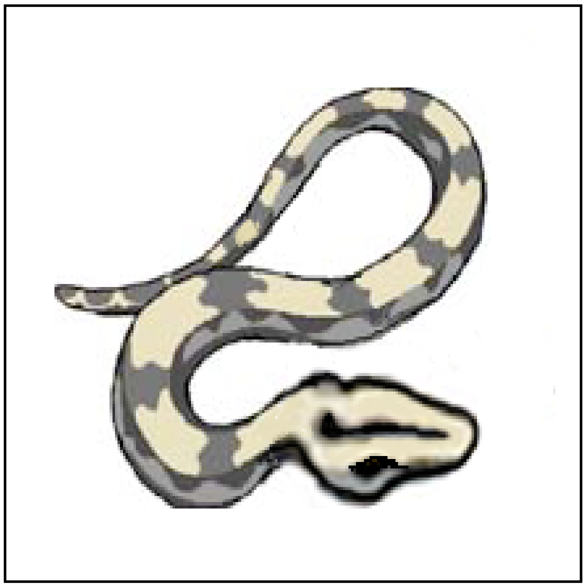


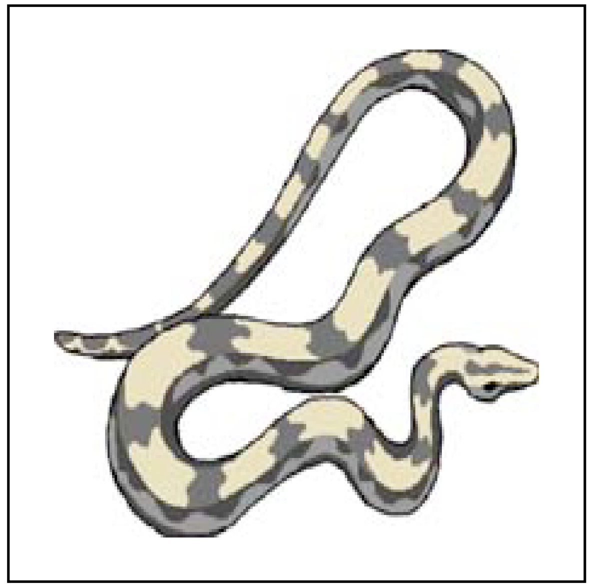


Mega-baby

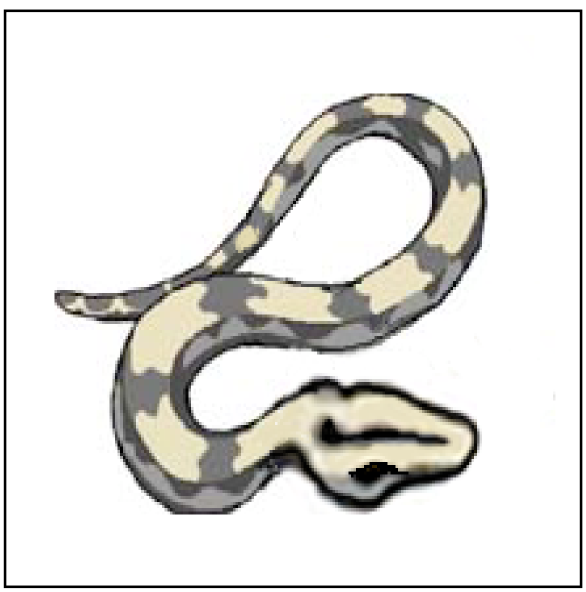


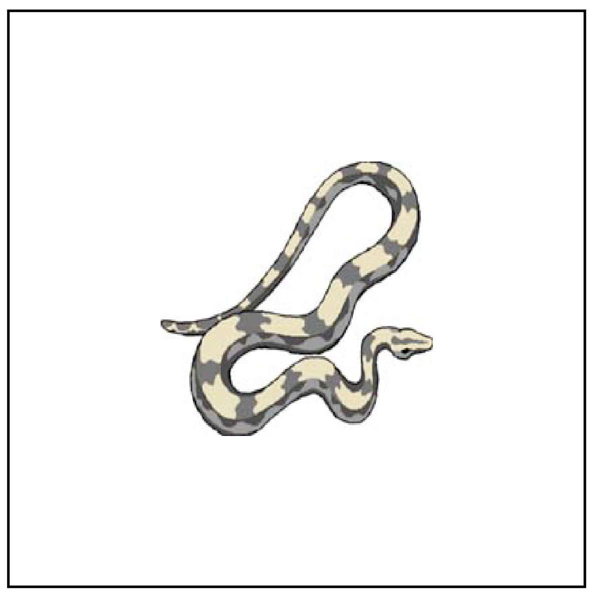
PYTHON (contd.)
Same-size



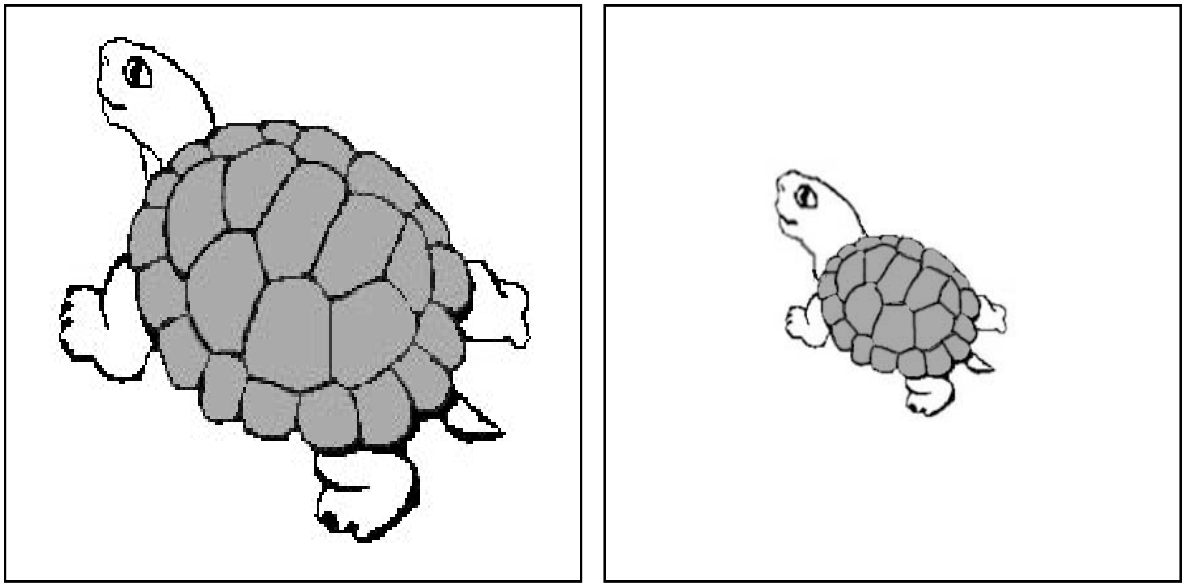


Conflict

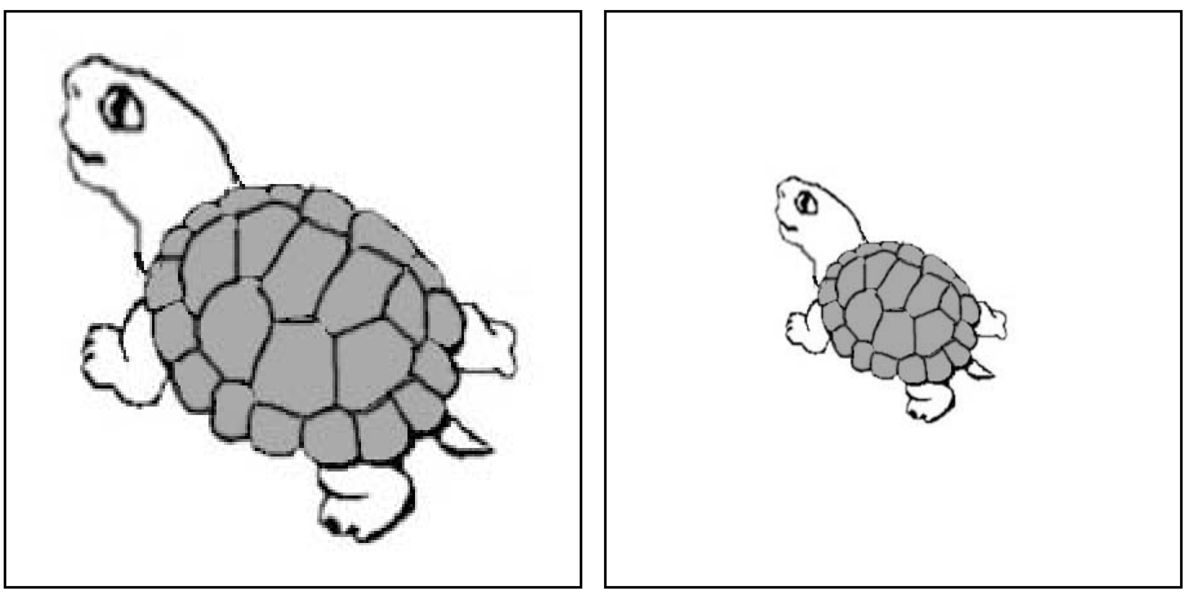




TURTLE
No Conflict



Mega-baby



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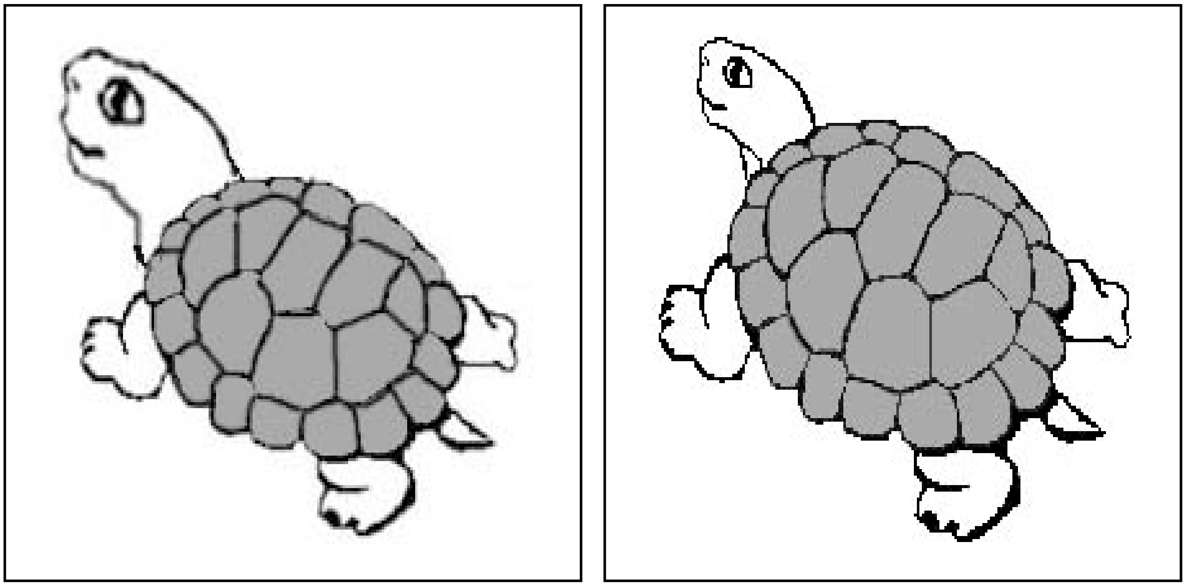

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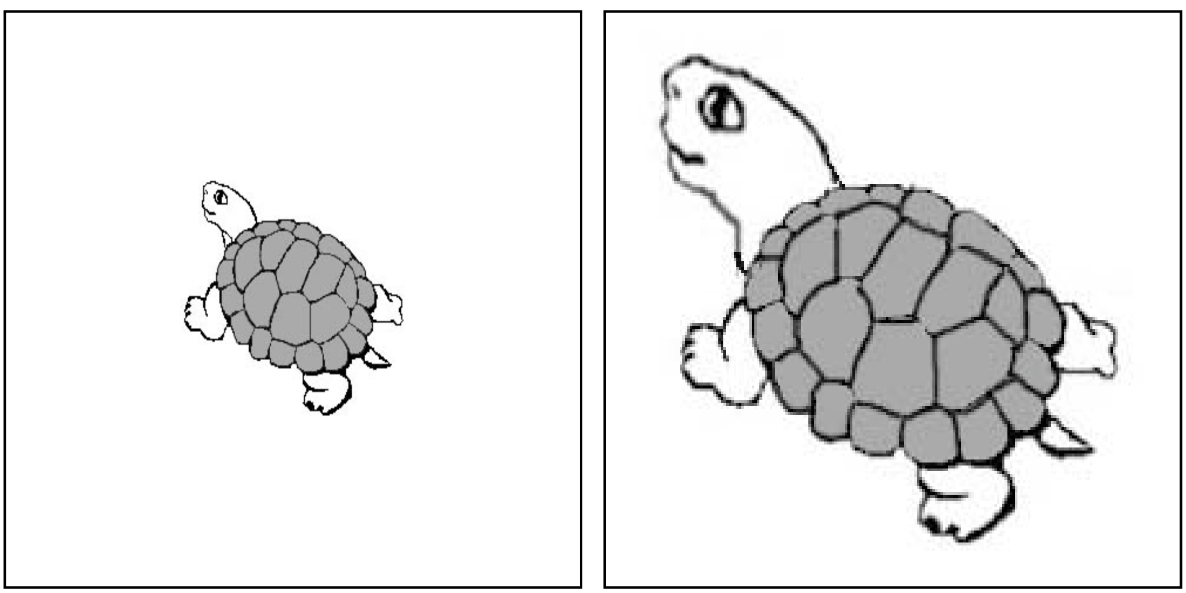
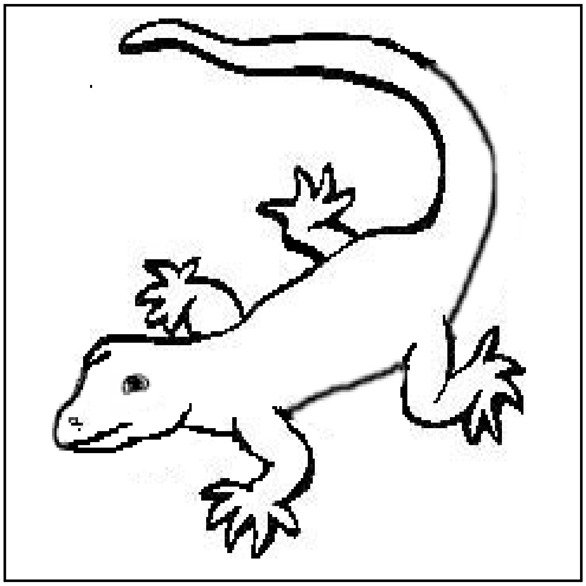
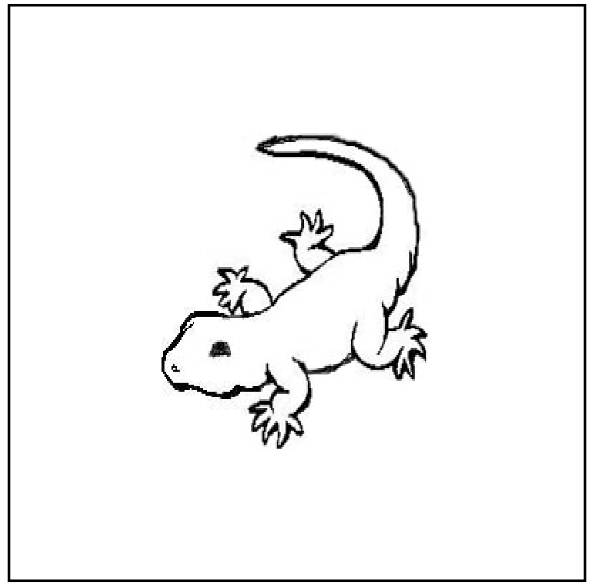


LIZARD
No Conflict

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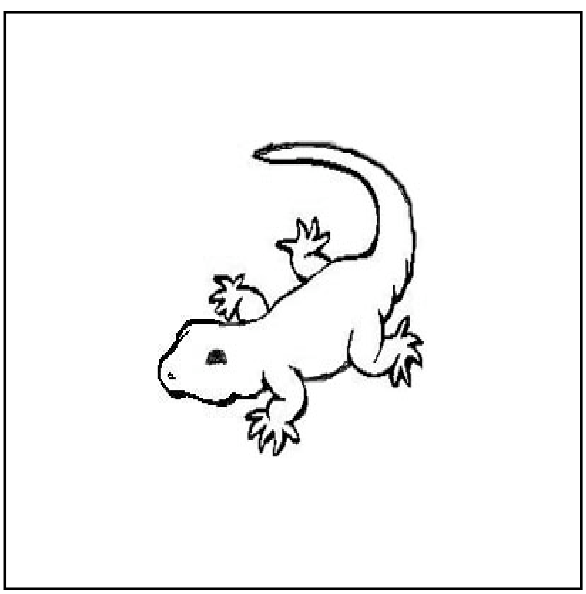
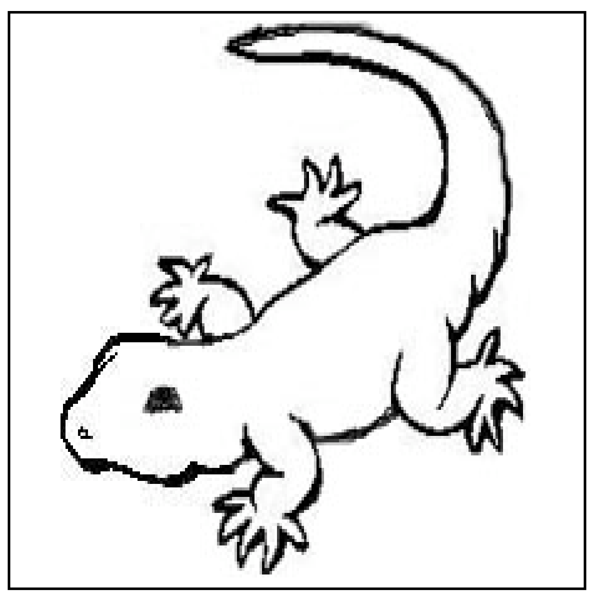

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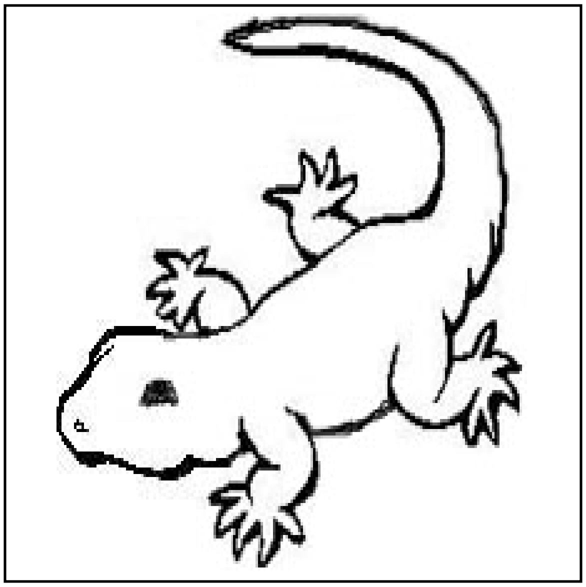 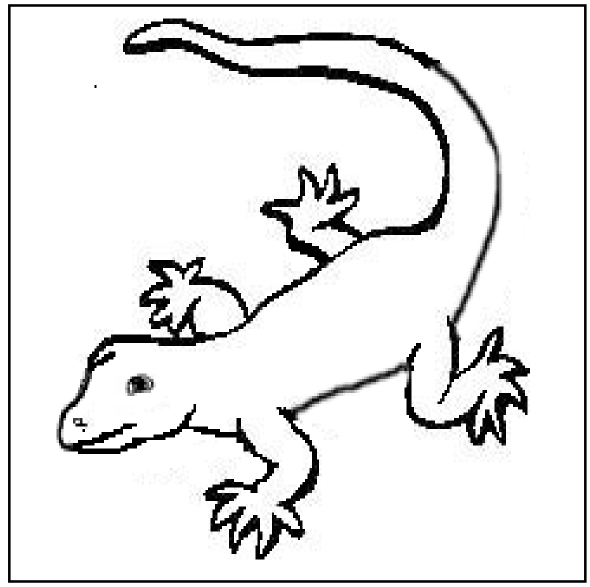

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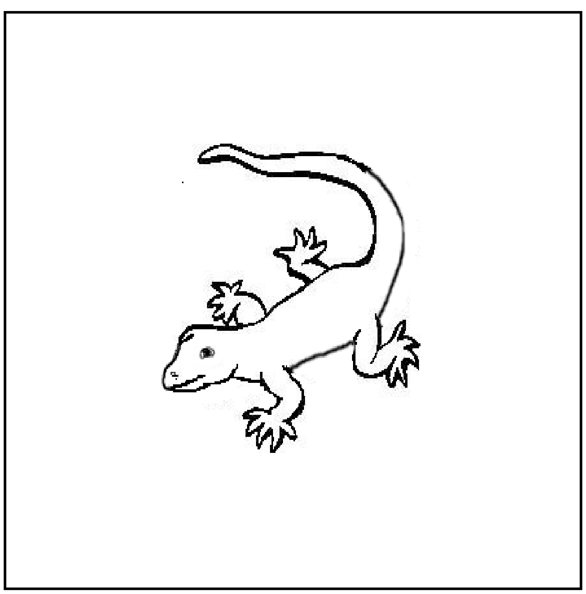
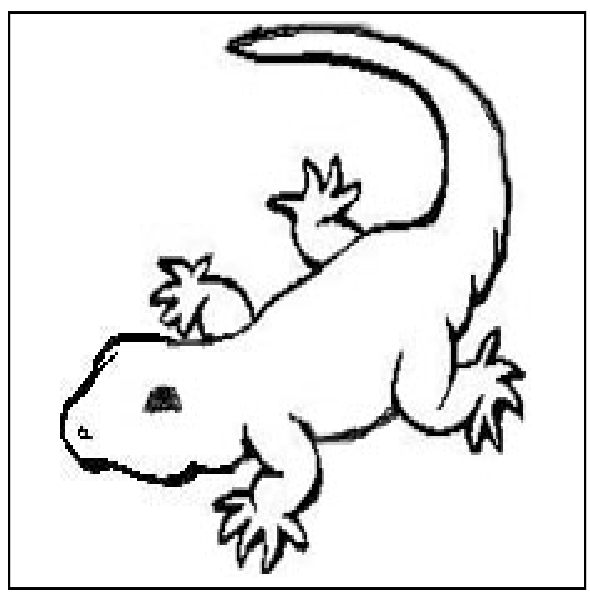
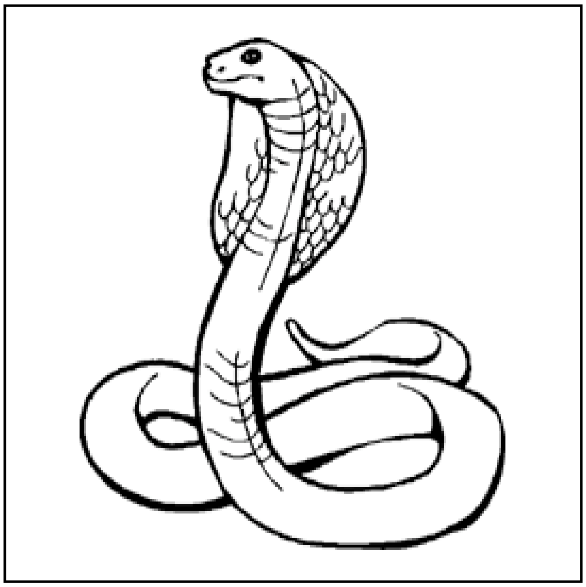
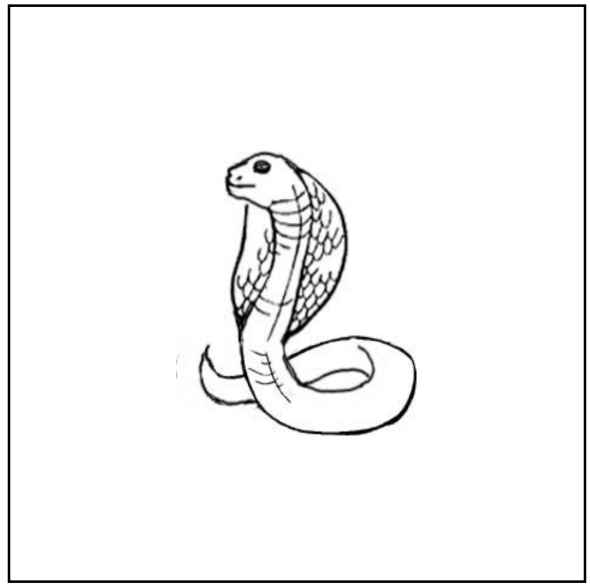
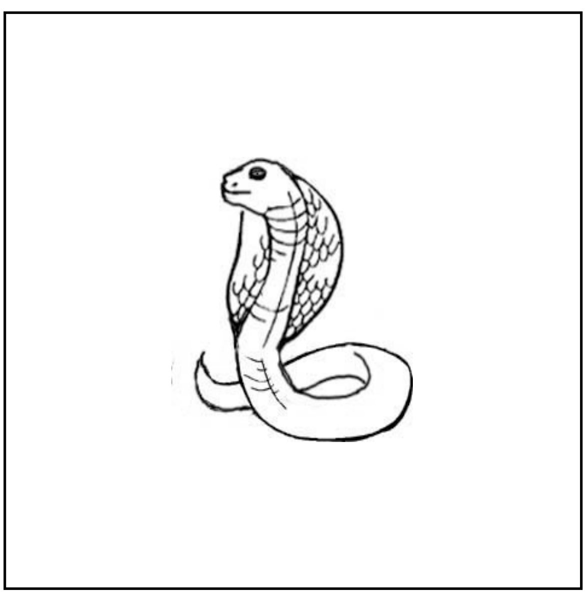
 

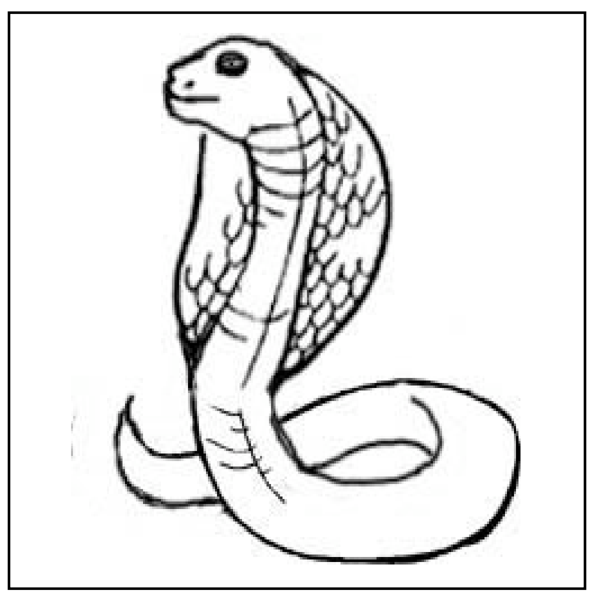
COBRA
No Conflict



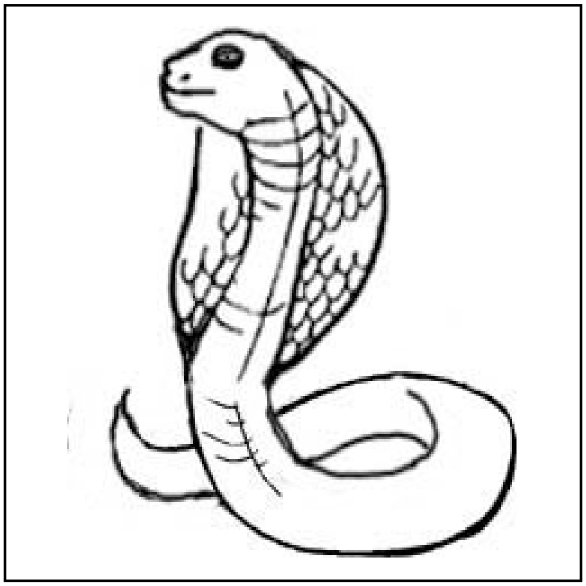


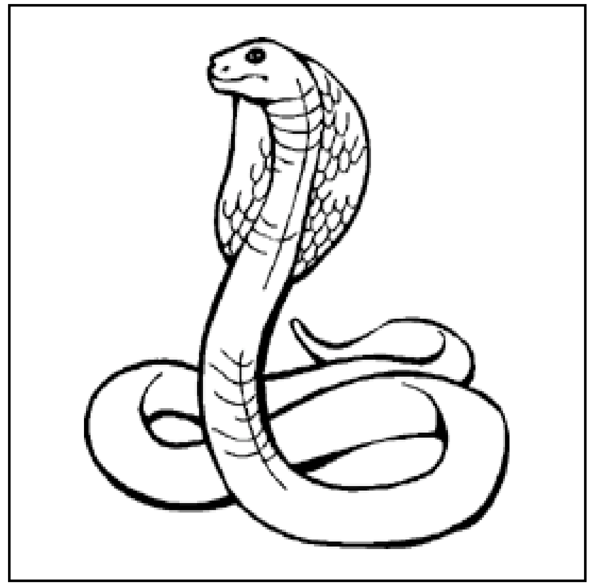
Mega-baby



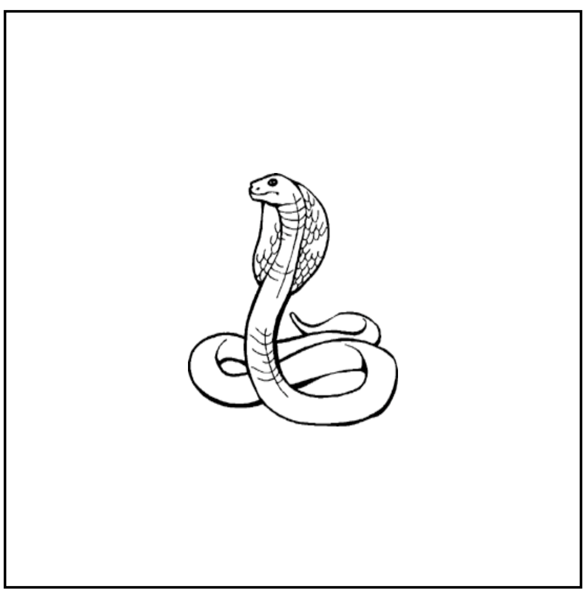


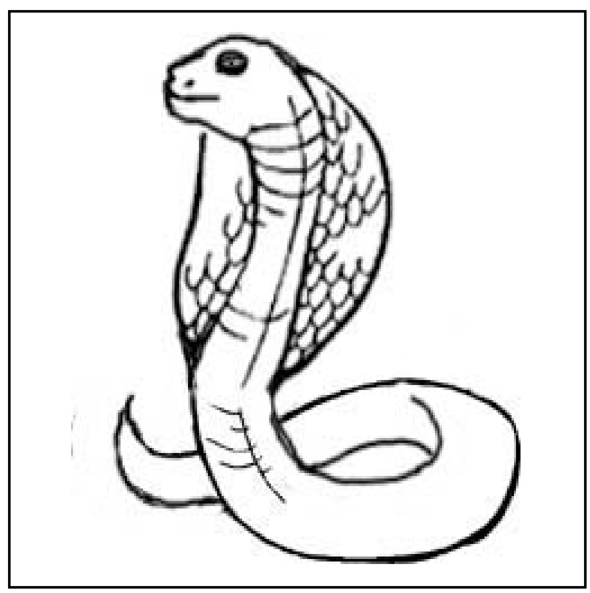
COBRA (contd.)
Same-size



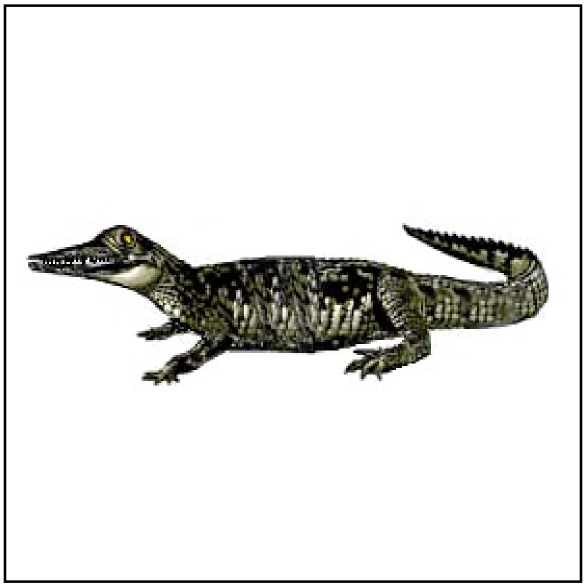


Conflict



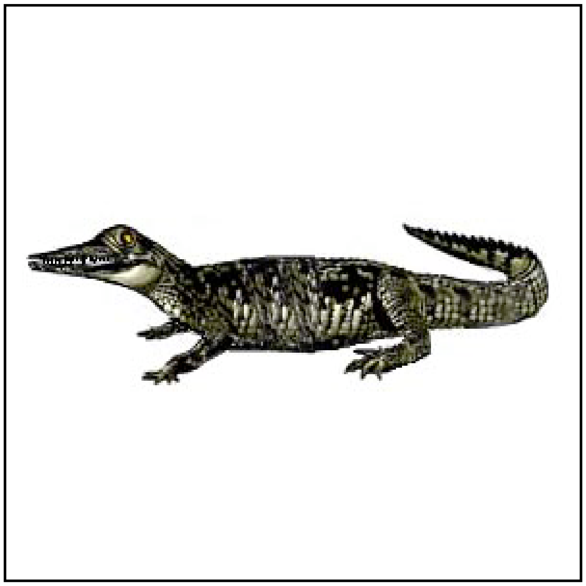


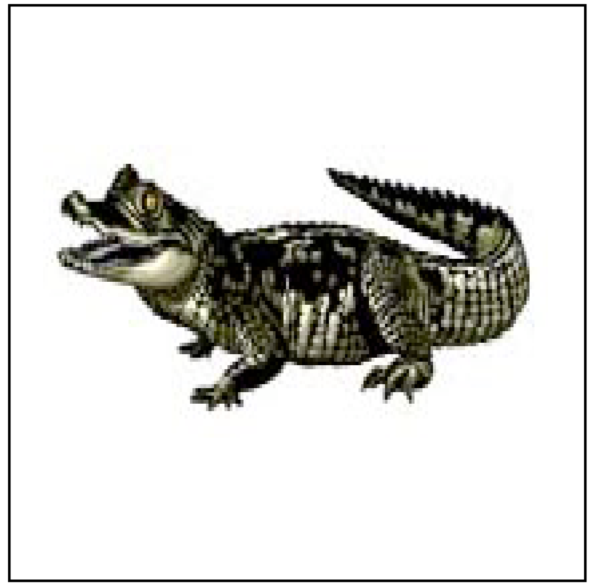
CROCODILE
No Conflict



Mega-baby

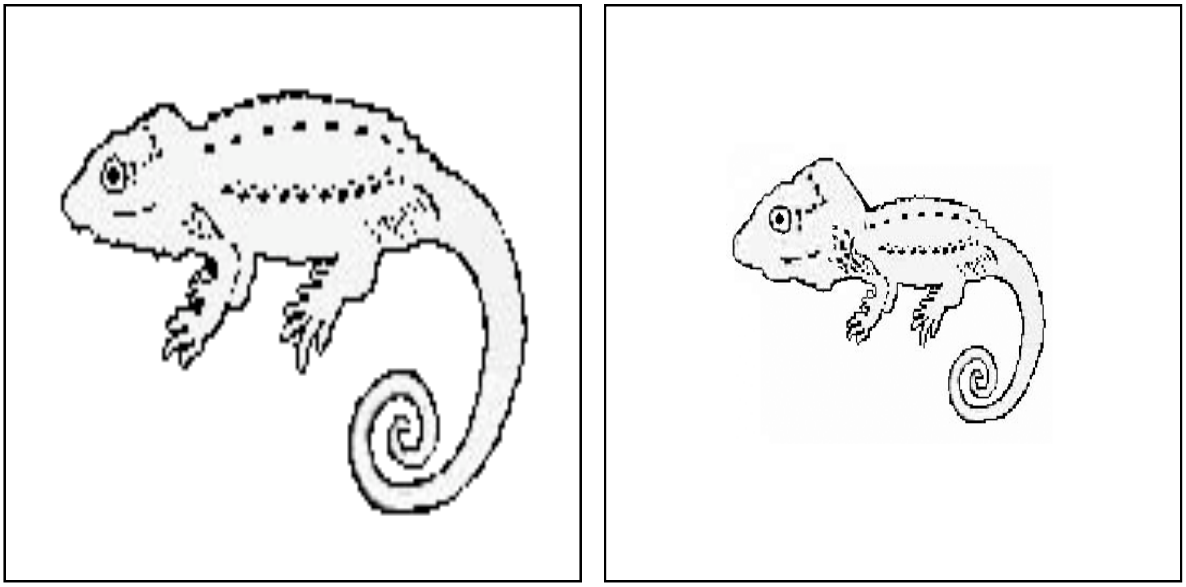
CROCODILE (contd.)
Same-size



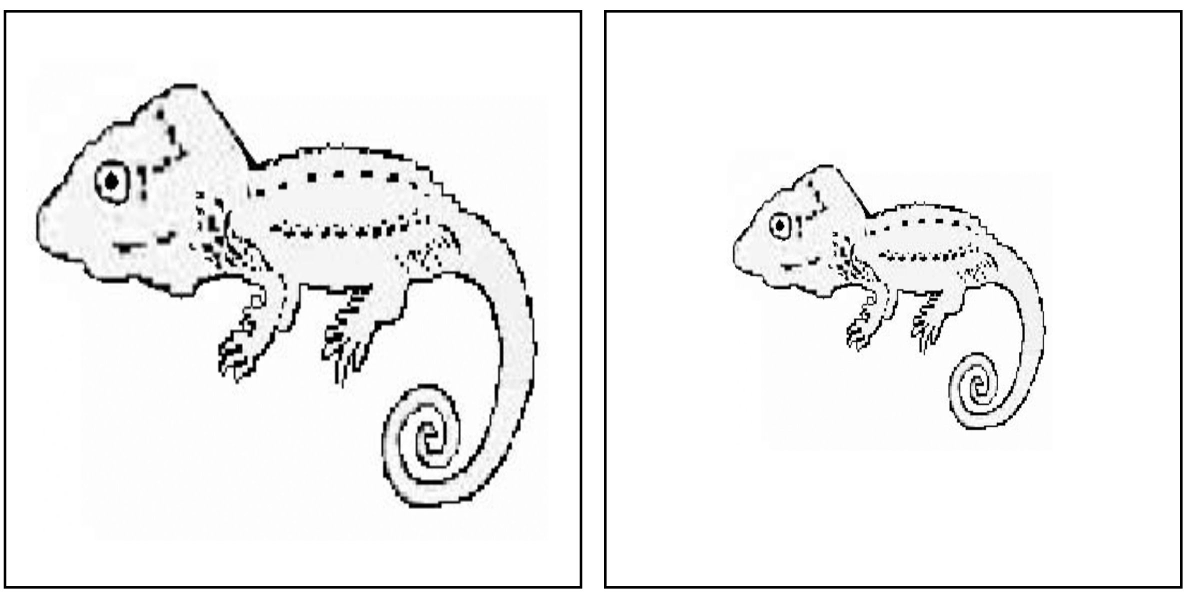


Conflict

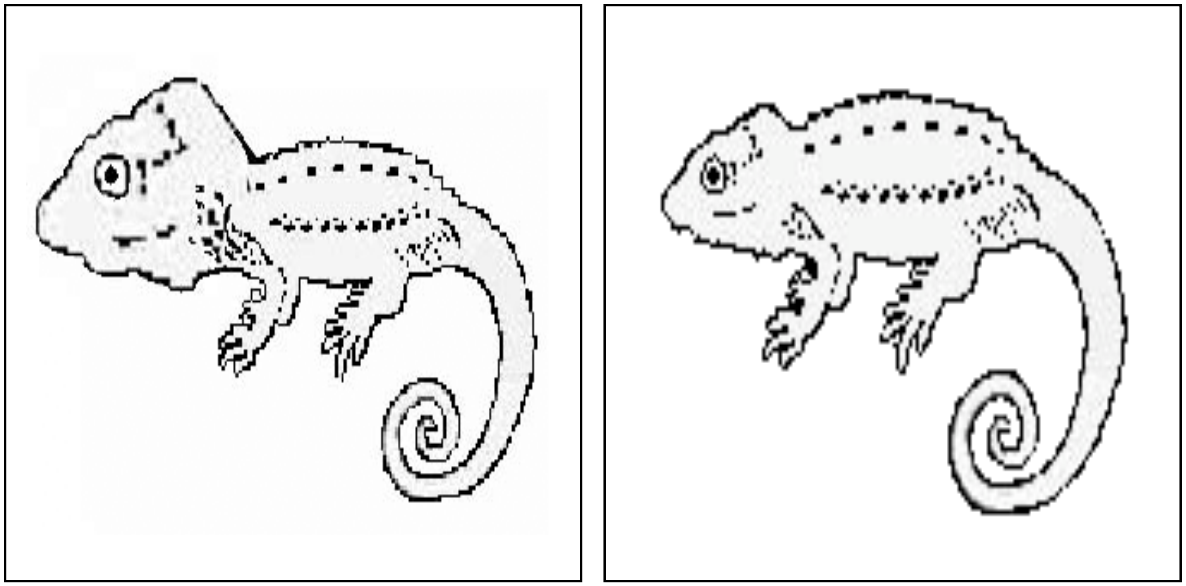
CHAMELEON
No Conflict



Mega-baby



CHAMELEON (contd.)
Same-size



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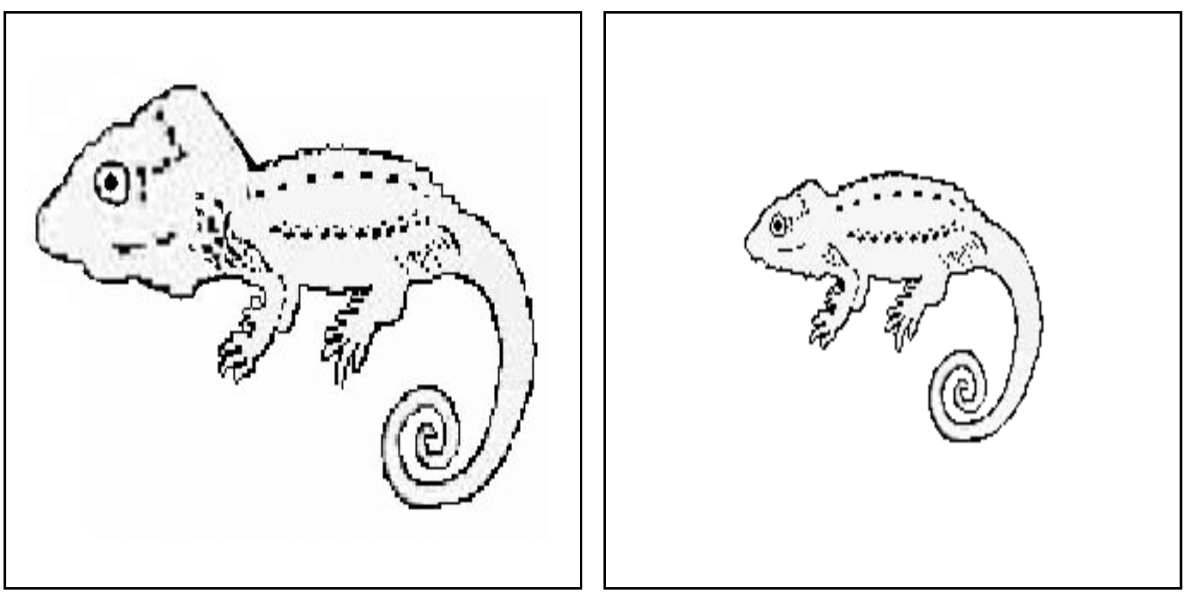
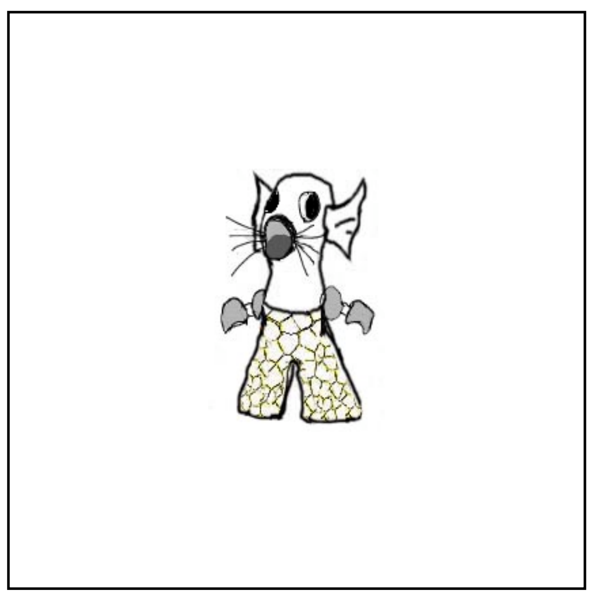


Appendix C

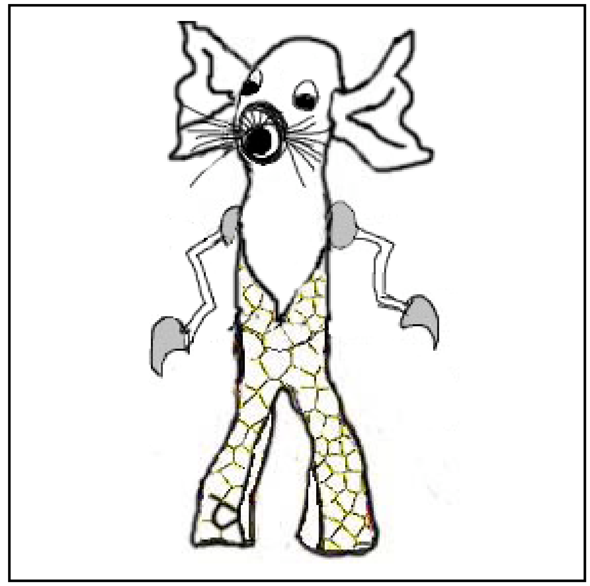
Sets of pictures from novel species used in Experiment III

CORNHUSK
No Conflict

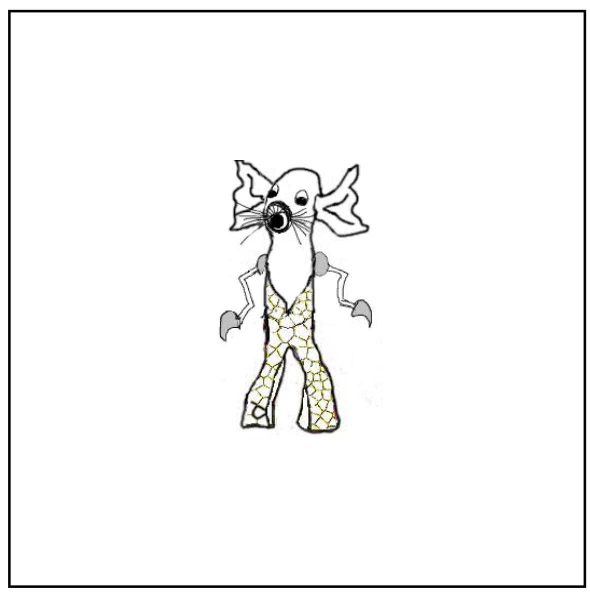

Mega-baby

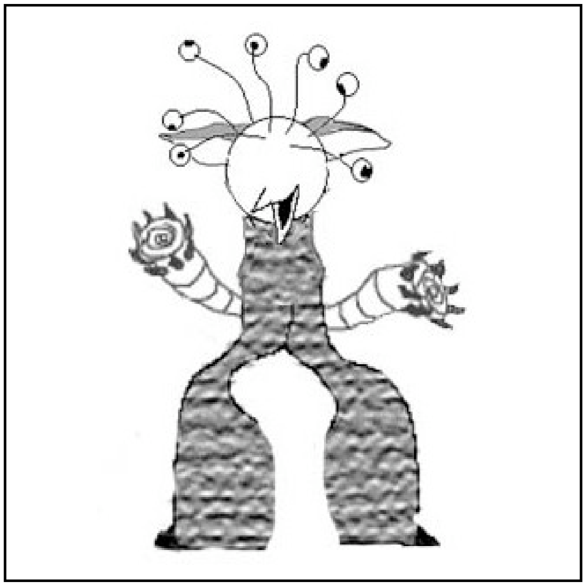
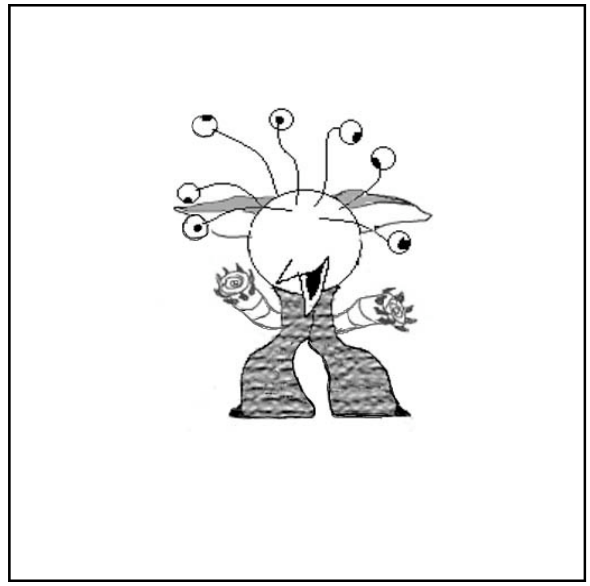
CORNHUSK (contd.)
Same-size

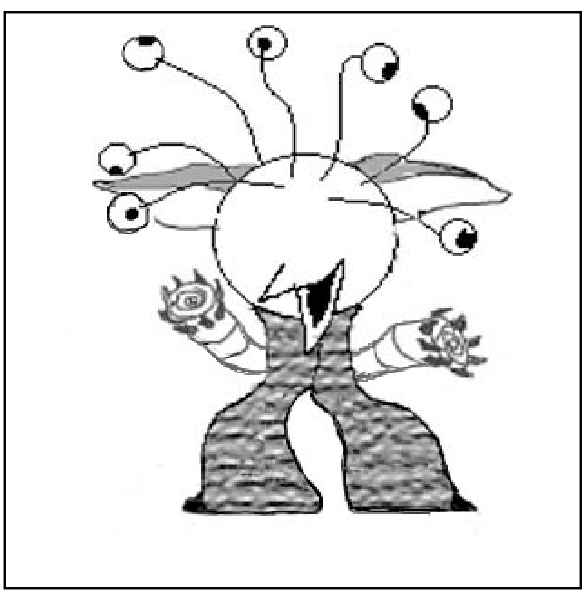
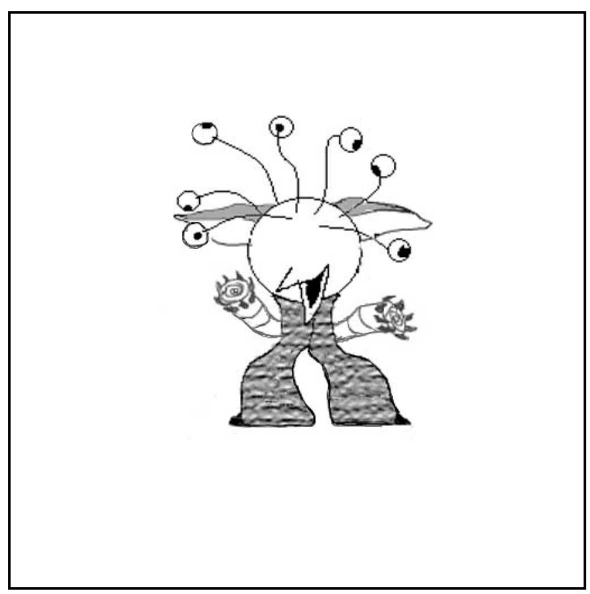
Conflict

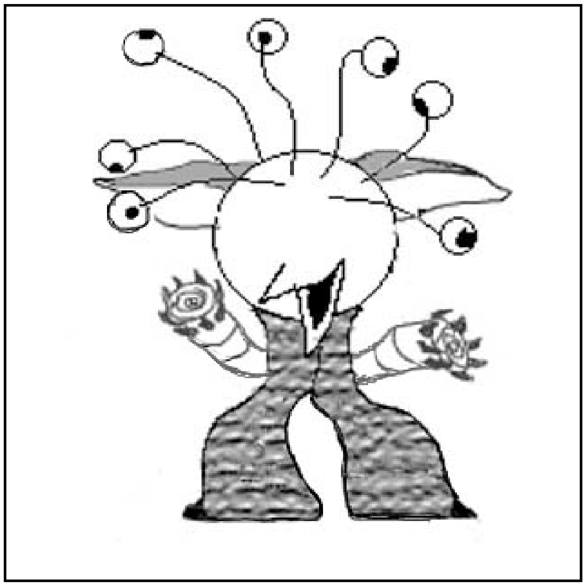
EYES
No Conflict

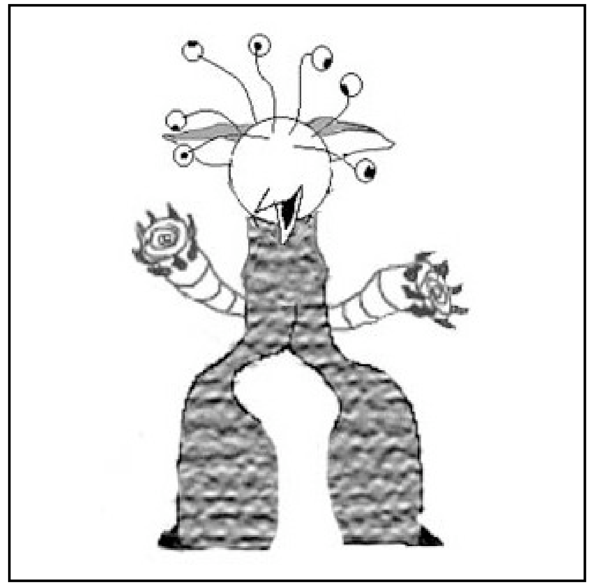



Mega-baby

EYES (contd.)
Same-size





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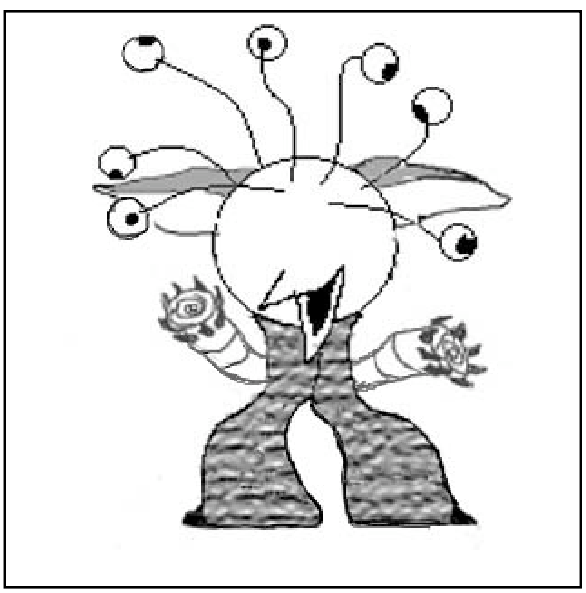
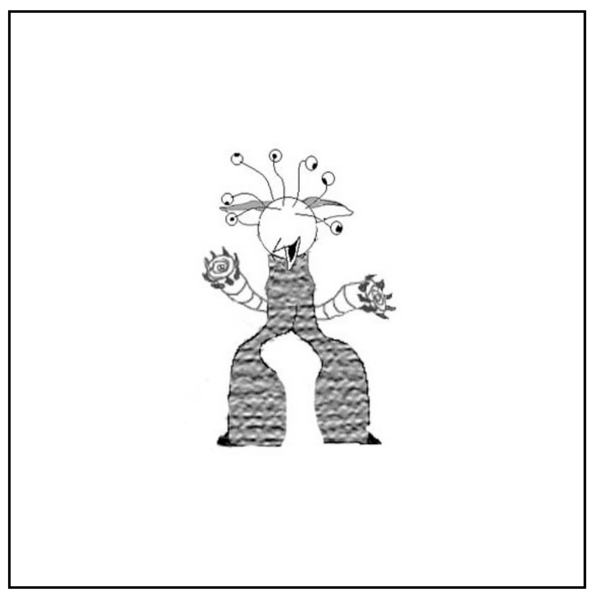
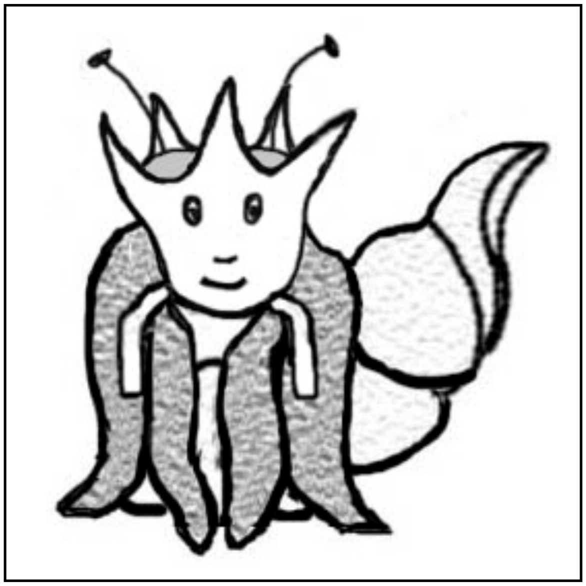
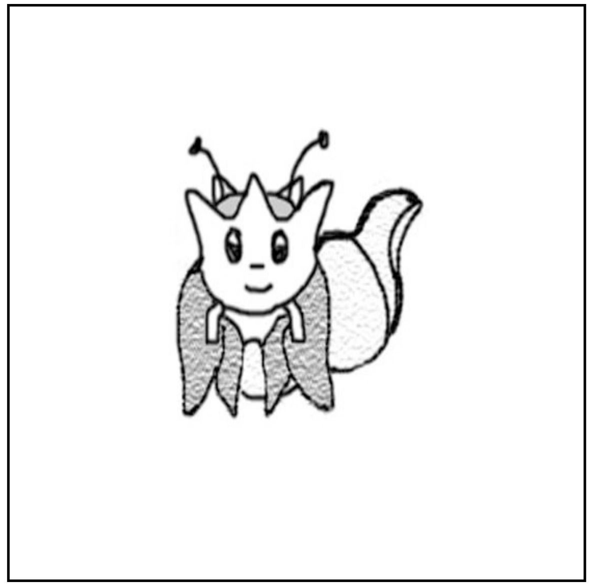


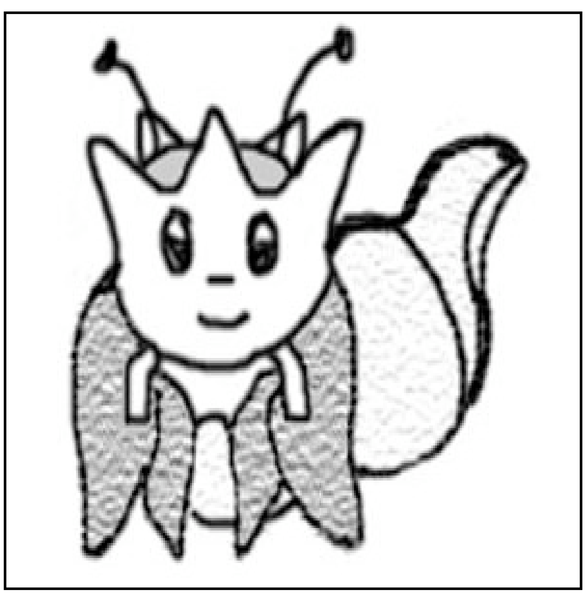


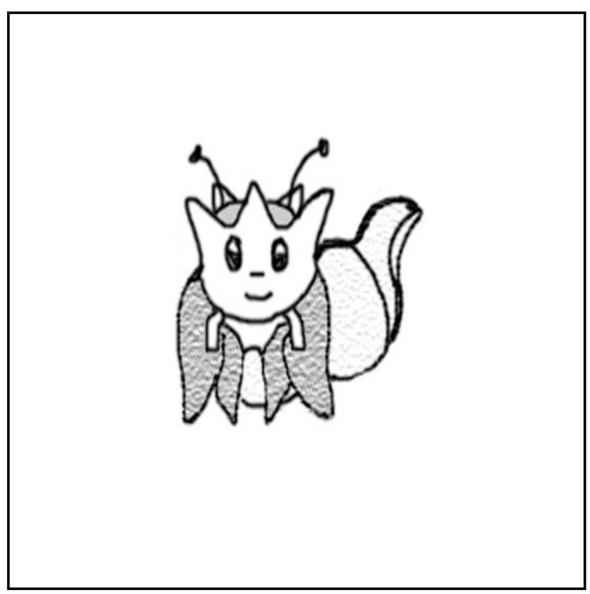
FLOWERSTALK
No Conflict



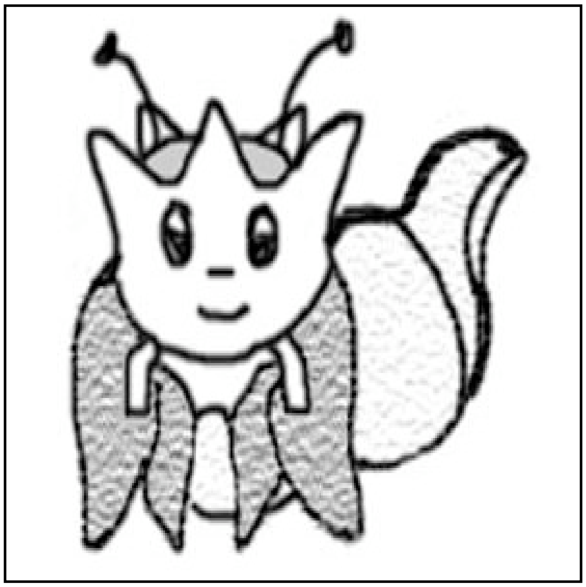
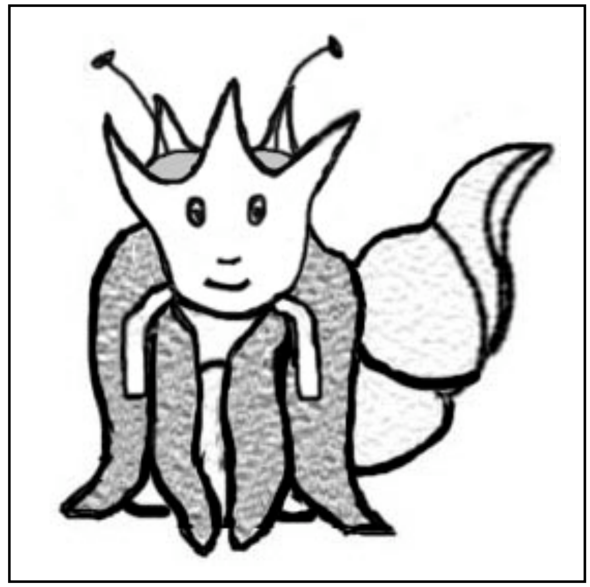


Mega-baby





FLOWERSTALK (contd.)
Same-size

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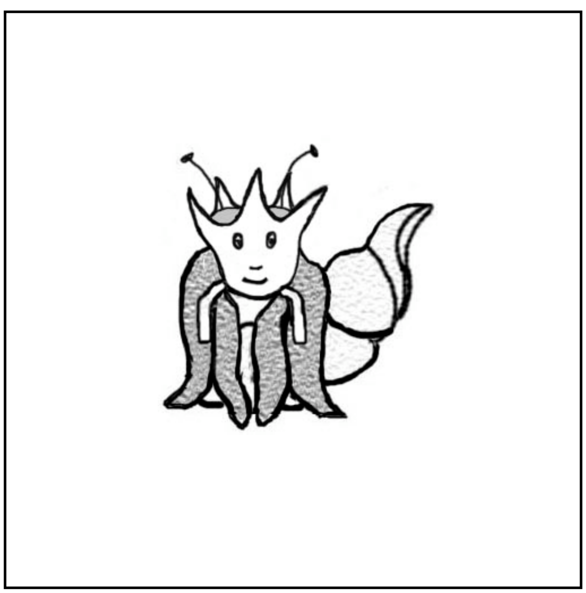
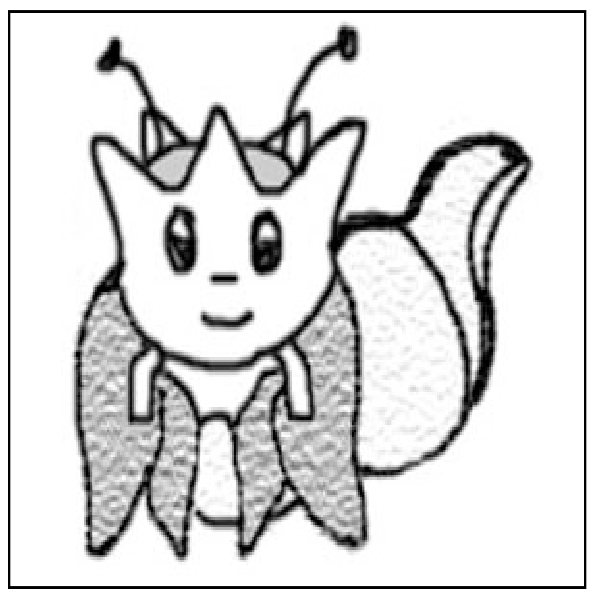
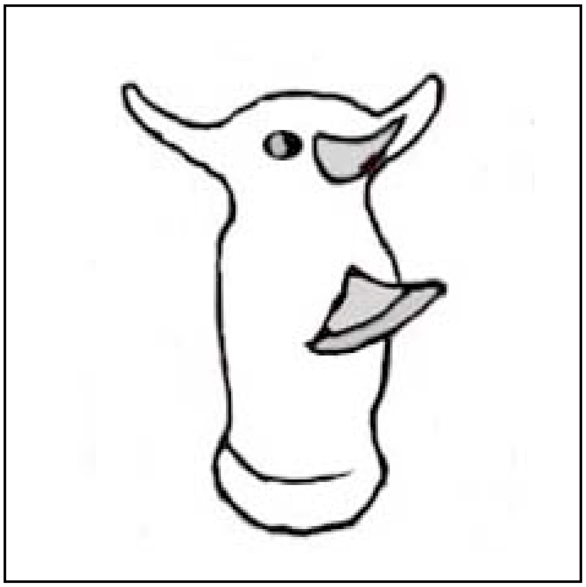
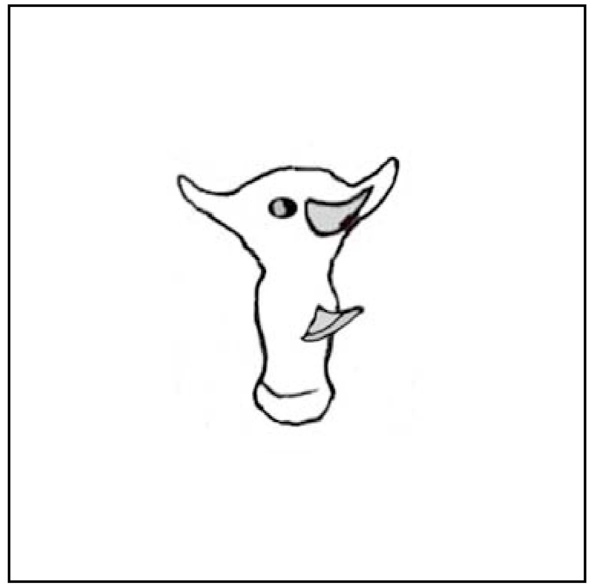



GREEBLE
No Conflict





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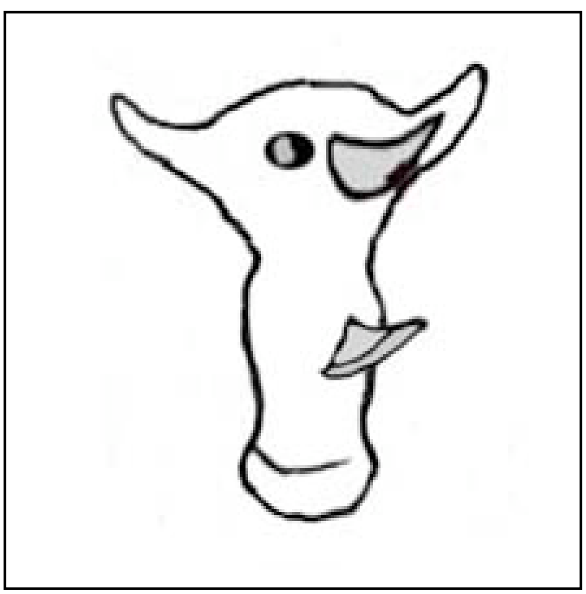
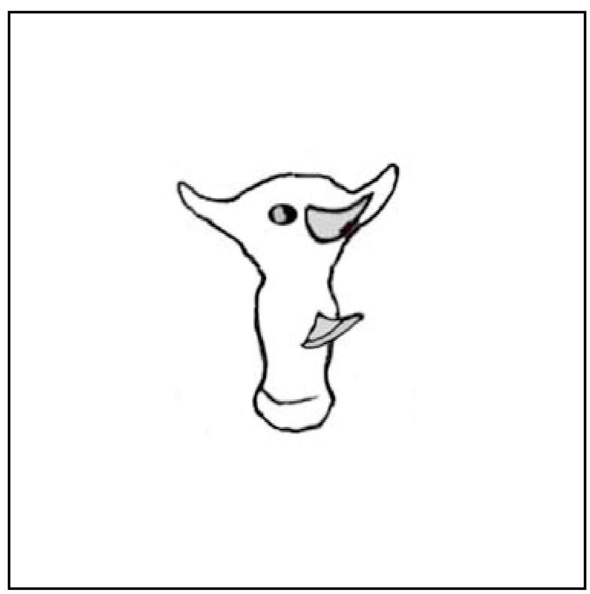
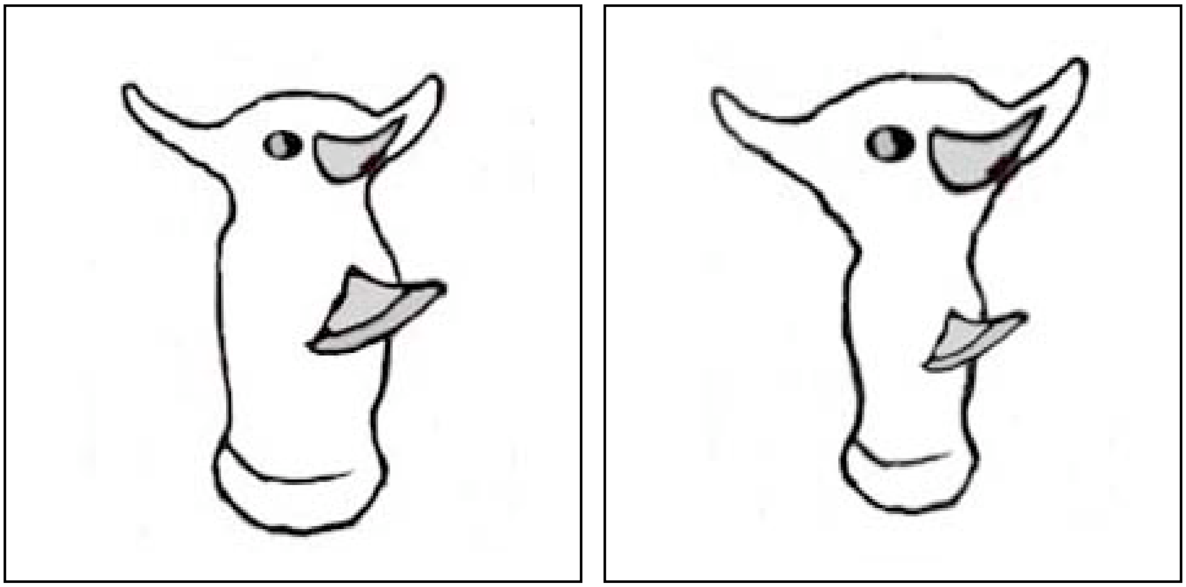
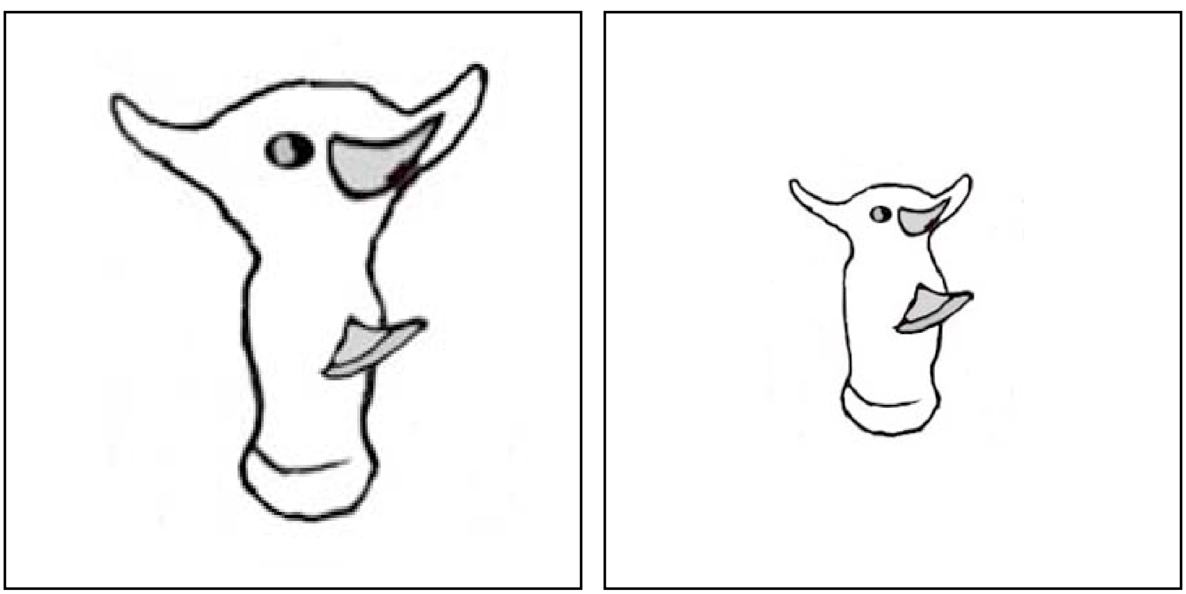




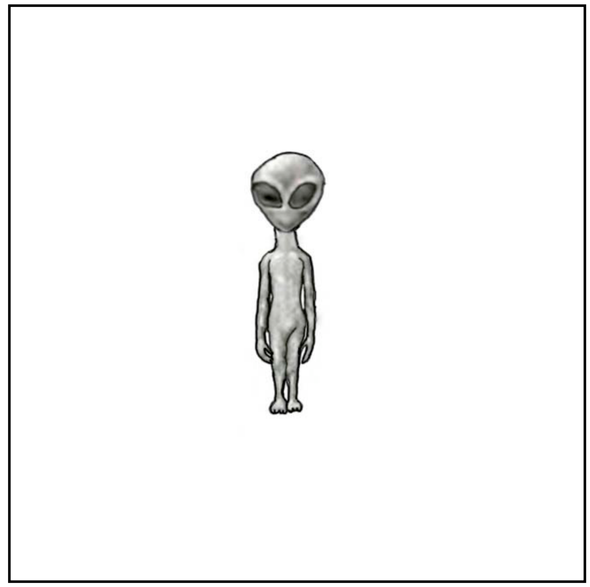
GREEBLE (contd.)
Same-size



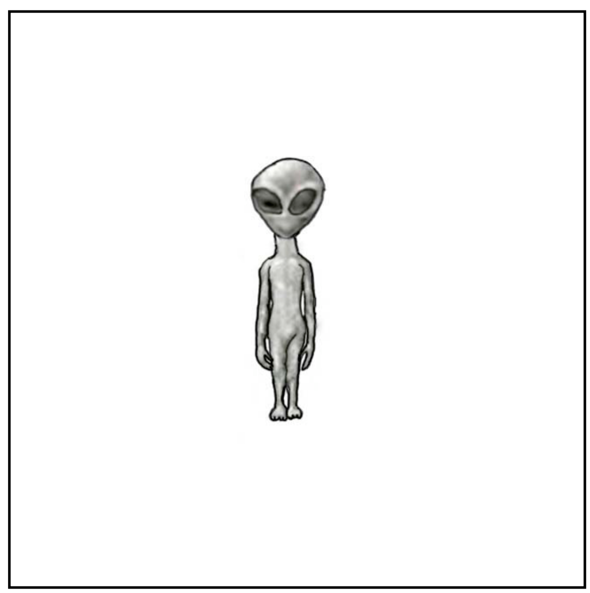
Conflict



GREY
No Conflict



Mega-baby



GREY (contd.)
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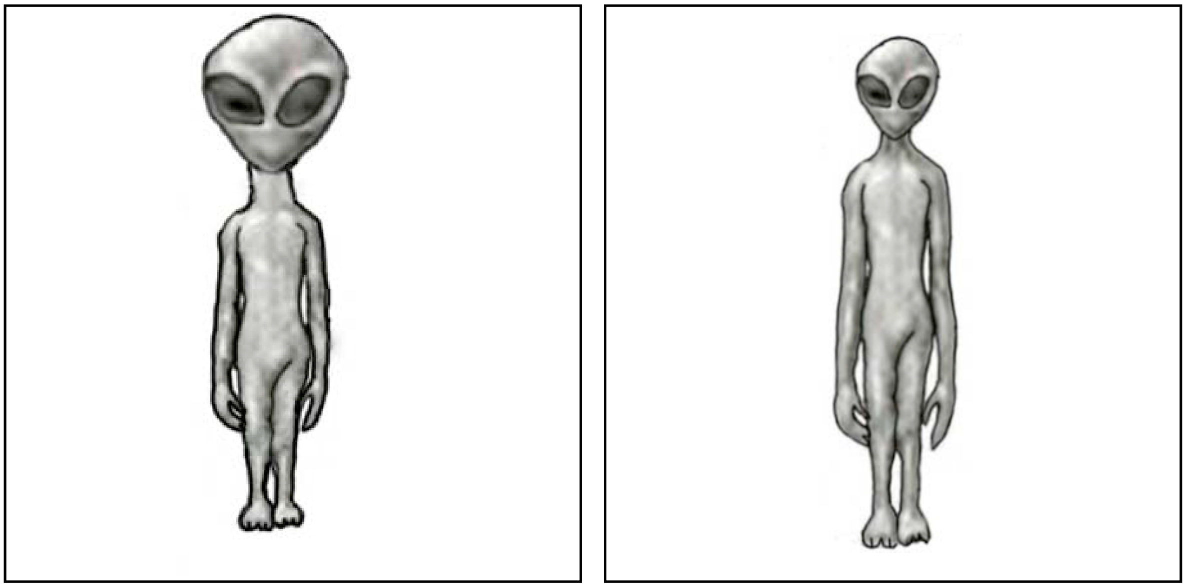
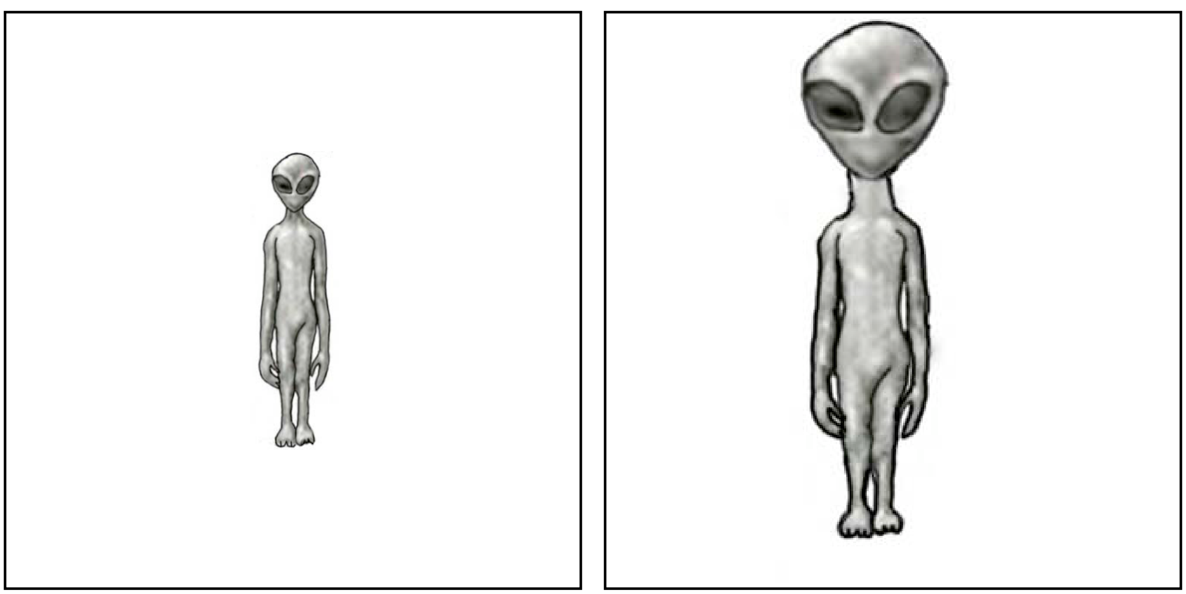
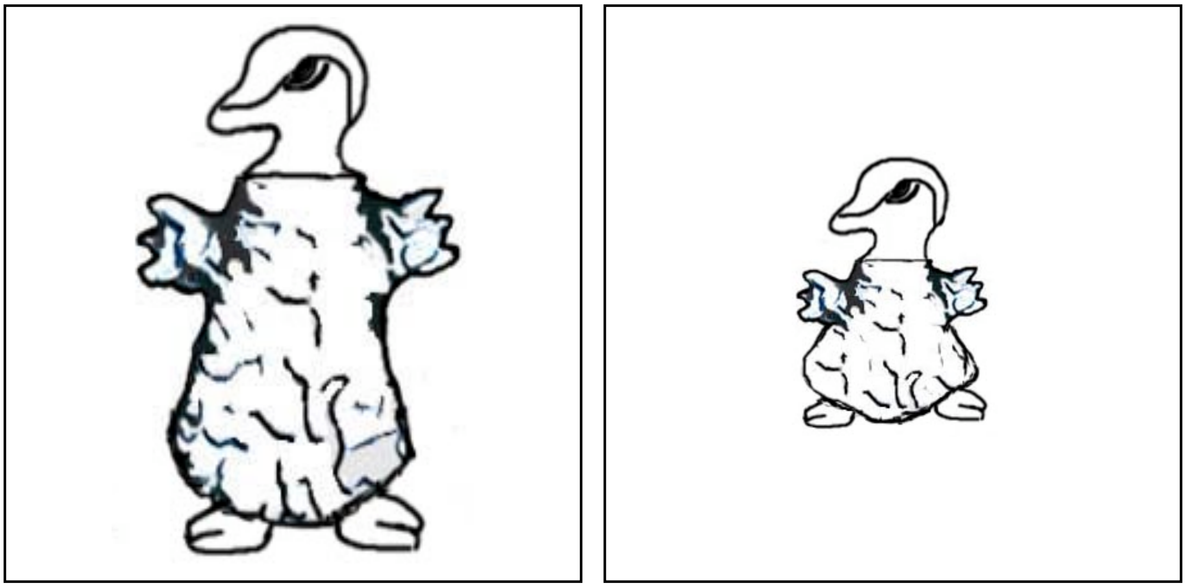


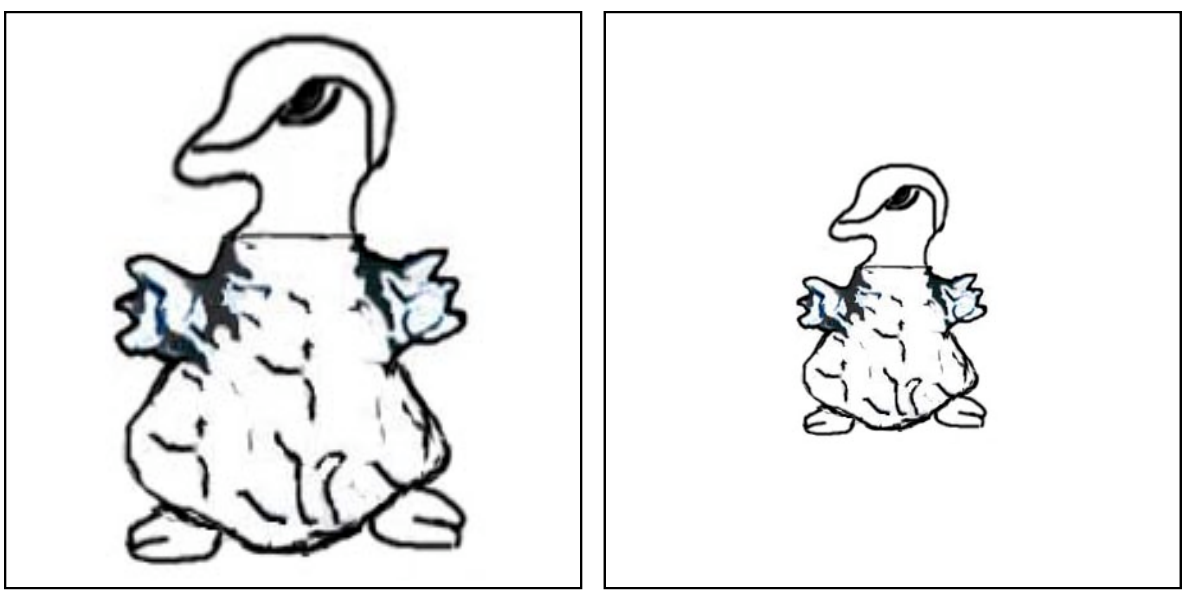
Conflict



GUMBY
No Conflict



Mega-baby



GUMBY (contd.)
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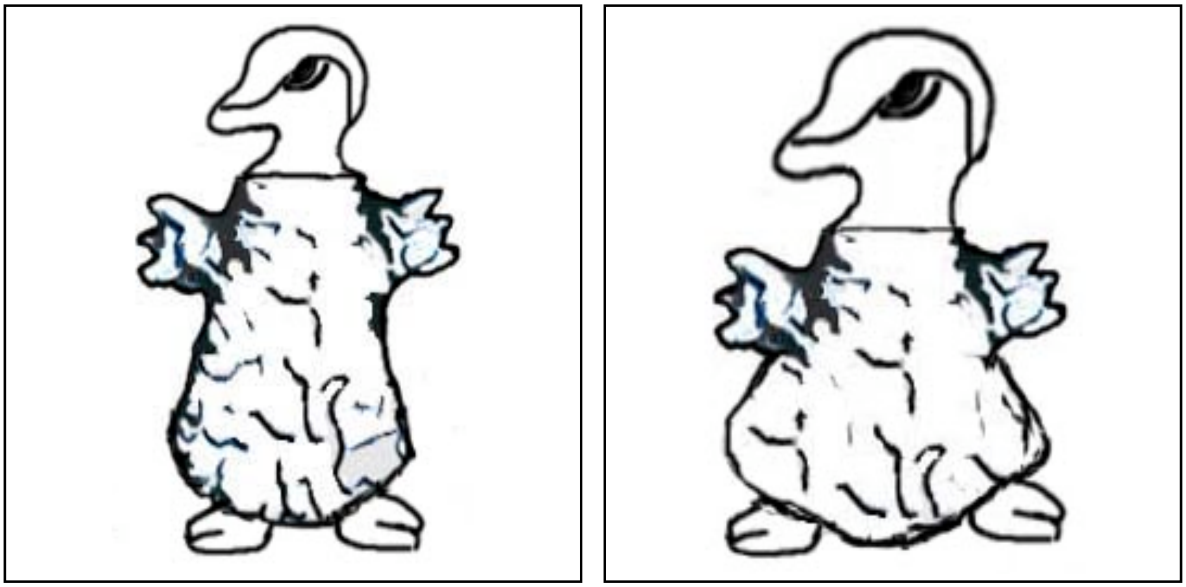
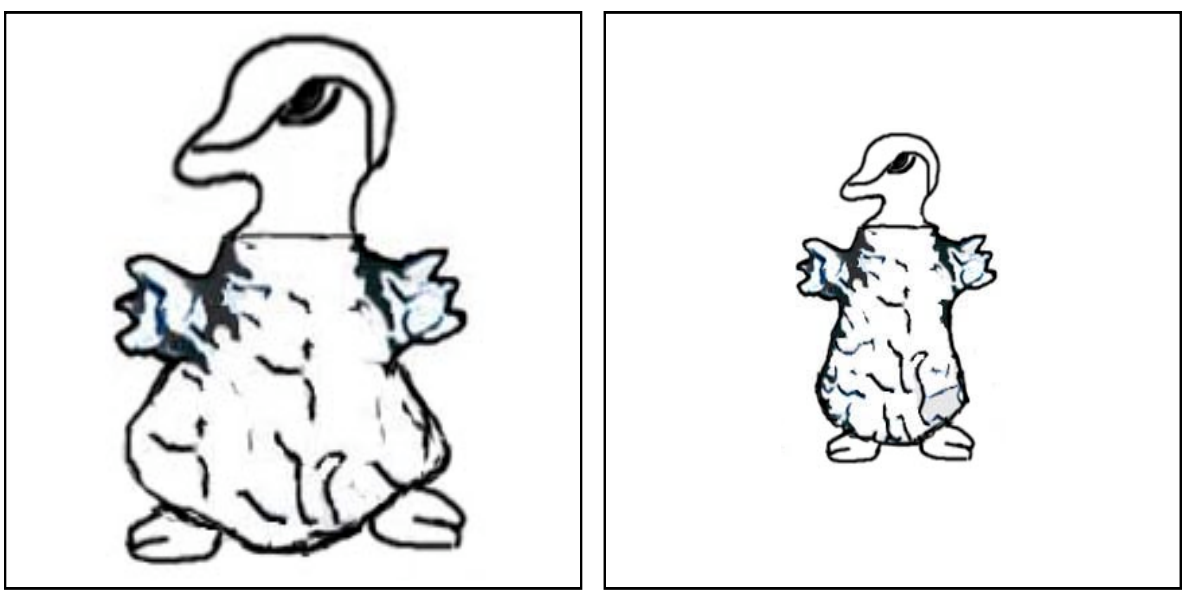


Conflict



Appendix D

Coding Scheme for Explicit responses

Coding scheme for explicit responses

Code # Category

1 SIZE [big or small]

a. Whole body or unspecified
b. eyes
c. face
d. head/hood/chin
e. nose (beak)
f. feet/hands/fingers/claws/other appendages
g. neck
h. mouth
i. shell

2 BODY PROPORTION
Need to say something is relatively bigger (smaller) for adult (infant). For example, they need to say that the head is bigger relative to the body for children than adults.

Direct Attention to

3 BODY PROPORTION FEATURES [bigger eyes for adult comes under size; bigger eyes for infant comes here; if they say baby is shorter (stature), it comes here].

a. limbs
b. eyes
c. face
d. head
e. nose

4 OTHER FEATURES THAT COULD BE RELEVANT
a. ears
b. hair
c. horns
d. tail.
e. wrinkles

5 IRRELEVANT FEATURES (e.g., white spot on belly, eyebrows etc.)

6 CAN'T CODE [e.g. "they look the same"; e.g. "eyes are roundish", "mouth is different"]

7 DON'T KNOW

<u>Note</u>: A special code indicating "identical stimuli" was given when participants mentioned that the two animals looked alike, or were the same. Less than 5% of all responses belonged to this category.

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