ABSTRACT

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| Title of Document: | THE ROLE OF SYNTAX AND CONTEXTUAL FRAME IN CHILDREN'S USE OF A CAUSAL THEORY IN REASONING ABOUT NATURAL KINDS |
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A central focus of cognitive development research is the nature and organization of knowledge. Some researchers claim that young children use an intuitive theory to help them understand foundational domains such as biological categories. In particular, researchers have studied whether children's biological concepts are embedded in a causal theory about the nature of living organisms. Two key features of this theory are the concept of biological essences and the use of inductive generalizations. This study examined the influence of contextual frame and logical conjunctions on access and use of the theory in elementary and middle school children. It also investigated whether that causal theory supports both inductive and deductive reasoning. Children were given inductive and deductive tasks involving natural kinds. In the inductive tasks the child was asked whether a property of an animal would be found in other animals varying in taxonomic distance from the animal. In the deductive task, children worked on syllogisms based on cues at different levels of a biological taxonomy. Older children were not as likely to make inductions about instances of less biological resemblance to the target. However they also made more accurate deductions regardless of level of the hierarchy. Inductive and deductive performance were not correlated. Whether the cues were stated in a sentence beginning with “if” or “all” had no significant impact on performance, but whether the problem was presented from the viewpoint of a scientist or a pet store owner affected performance. These results were used to re-examine the basic tenets of essentialist thinking and the nature of developmental changes in reasoning about biological kinds.

# THE ROLE OF SYNTAX AND CONTEXTUAL FRAME IN CHILDREN'S USE OF A CAUSAL THEORY IN REASONING ABOUT NATURAL KINDS

By

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**Dedication**

**To my parents – Hubert L. and Esther L. Hammond**

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It is with a true sense of gratitude that I thank the many family members, friends, professors and colleagues who have supported me through this process. They have encouraged, cajoled and cheered every step of the way.

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# Chapter 1: Induction and Deduction in Natural Kinds

A central concern of cognitive development research is the nature and organization of knowledge. Early philosophers such as John Locke and David Hume proposed an associative theory of knowledge suggesting that infants had only minimal skills at birth. Using these minimal skills they developed their knowledge by associating contiguous experiences in their environment thereby slowly expanding their knowledge base. This suggests that children are blank slates at birth (Locke, 1959/1671; Pinker, 2002).

By the 1920's and continuing through the 1970's, Jean Piaget proposed an alternative to the associative or empiricist theory. He proposed that children have more than just associative skills. Instead, they are born with motor and perceptual capabilities that allow them to explore their world in order to construct concepts and understandings. Piaget's constructivist perspective included several new major ideas that are of importance. First, that development is achieved in stages. These stages must progress in a particular order and each stage represents major qualitative shifts for the child in multiple domains. Thus, when children do move from one stage to another, this move affects many concepts at the same time (Flavell, 1971). Also, according to this theoretical perspective it is not possible to attain abstract learning capabilities and concepts before concrete concepts and reasoning skills have been mastered. Piaget argues that true conceptual development emerges slowly and is found only in older children and adults (Flavell, 1963).

By the mid - 1970's Piaget began to fall from favor and other groups of researchers proposed a new model of knowledge acquisition arising from the field of artificial intelligence (AI); the information processing model (IP). This model suggests that the way in which knowledge is stored and retrieved forms the basis for how knowledge is gained (Klahr & MacWhinney, 1998). IP theorists suggest that children pay attention to the environment, store information in long and short term memory and then apply strategies to retrieve and expand their knowledge. As they mature and gain more experience they increase their strategic skills allowing them to overcome processing limitations such as memory constraints. In this model the child's thinking is synonymous with processing information and building knowledge. Development is not stage-like, but instead depends on a metacognitive approach where children continuously adjust their strategies to overcome limitations by using their specific content knowledge and experiences. This requires a precise analysis of change and the incorporation of new contributions of ongoing cognitive activity. Stage development is no longer valid with IP because the child is in a constant state of change through self-modification and because reasoning proficiency is content specific (Siegler & Alibali, 2005).

At the opposite end of the spectrum from the empiricism described by Locke and Hume is the notion of nativism. As described in the 1700's by philosopher Immanuel Kant and more recently by linguist Noam Chomsky (Chomsky, 1972), nativism argues that important concepts are present at birth. Instead of being developed through experience they merely unfold with maturation much the way that physical development or puberty unfolds for an individual child. This model assumes that knowledge is in place, it is simply a matter of unlocking it. An important proving ground for neo-nativists is the development of reasoning about natural kinds.

With respect to natural kinds, some prominent researchers have taken a neo-nativist stance and claimed that young children use an intuitive theory to help them understand particular foundational domains, such as the nature of mental life, biological categories, and intuitive physics (Gelman, 2003; Gelman & Wellman, 1991; Haslam, Bastian, & Bissett, 2004; Heyman, Phillips, & Gelman, 2003). For example, researchers claim (Gelman, 1988, 2000, 2003; Gelman & Coley, 1990; Gelman & Markman, 1987; Gelman & Medin, 1993; Keil, 1989; Medin & Ortony, 1989) that young children's biological concepts are embedded in a causal theory about the nature of living organisms, a subset of the natural kinds. Two key features of this theory are the concept of biological essences and the use of inductive generalizations. The theory implies that inductive generalizations are used by the child to organize and extend knowledge about the biological world.

This new study tests the claim that young children are intuitive theoreticians by examining whether a causal theory supports both inductive and deductive reasoning in the domain of biological concepts. It also explores the potential influence of frame and linguistic factors as they influence access and use of the theory.

This chapter is organized into four parts beginning with a general definition of the term natural kinds and an overview of inductive and deductive reasoning. The second section is a description of three theories of categorization including classical categorization, semantic theory, and concepts as theory. Basic, subordinate, and superordinate category level definitions as well as property inheritance are presented in the third section. The fourth section describes some of the research in biological understanding that supports the "concepts as theory" theory and includes discussions of category levels, labels, argument strength and folkbiology.

### *Natural Kind and Deductive/Inductive Reasoning*

Both inductions and deductions are made across category members; however, the type of category (e.g., natural kinds) will make one kind of inference easier or harder than another. Current research on concepts has focused on natural kinds in relation to both inductive and deductive reasoning.

#### *Natural Kinds*

Natural kind is a descriptive for a category of naturally occurring instances of living organisms with insides that can be examined to gain information about their functioning. The information gleaned from this examination is assumed to show three specific consistencies. First, natural kinds have properties consistent across the class or kind. Whatever characteristics make a person part of the class called humans will also be found in other instances of the natural kind called humans. Next, natural kinds are consistent across generations. Whatever traits and characteristics make a person a human will be the same traits and characteristics that make her progeny human. Finally, whatever characteristics make a person human today are the same characteristics that will make a person human tomorrow.

These three consistencies are important because they allow a reliable categorization of instances of natural kinds and give rise to the use of both deductive and inductive reasoning. For example, the dissection of a frog reveals information that helps us understand how the frog continues to be what it is. Under a microscope, even more detailed information may be revealed. We also know that the insides of these naturally occurring instances of a kind will be exhibited in the next generation in basically the same way. The dissection of a table or chair would not reveal much in the way of information about how the chair continued to be what it was, nor would we assume that anything that we did find could be applied in any reasonable way to a description of the next chair that we dissected.

People intuitively assume that natural kinds contain some hidden essence that defines what the kind is, that is, what makes a turtle a turtle or a lion a lion. This essence is shared with other categorical members and permits generalizations from one member of the kind to the next. Thus, natural kinds are categories that permit inductions. The essence is comprised of characteristics or traits that are not outwardly obvious, but that serve as criteria for class inclusion because they represent the true nature of an item and give it a conceptual identity. Appreciation of this essence is considered to be intuitive knowledge; therefore everyone does not necessarily describe it in the same terms.

Whereas a child might identify an animal as a lion and claim that the identification is true because of the way the animal acts, an adult may claim that the animal's DNA is the essence of the animal and what makes it a lion. In both cases, although the level of descriptive sophistication is markedly different, the essence remains an intangible quality, which is considered a permanent element of the natural kind's being and something that helps define its place in a taxonomy of natural things.

The category of natural kinds lends itself to the use of both inductive and deductive reasoning. Induction is used to extend information about common properties to new instances and deduction is used to validate generalizations.

*Deductive Reasoning*

We all use logic as a problem solving strategy to help us understand the world around us. In the most basic terms, we are using the truth of one statement to infer the truth of other statements.

Deductive reasoning is the type of logic formula that we apply to analyze information where a reliable conclusion can be stated. A deductive scheme or syllogism represents a formal argument consisting of a major and minor premise and a conclusion. For example, suppose we know "If it's a blue jay (represented by the letter P), it has vitamin K inside (represented by the letter Q)." This is stated as "if P, then Q." It is possible to use this truth to deductively infer other conclusions. For example, if I tell you, "I have a blue jay in my hand" and then I ask you, "Does it have vitamin K inside?", you could say yes and be certain that you were correct (Modus Ponens). If I tell you, "This is not a blue jay in my hand," and then I ask you, "Does it have vitamin K inside?" the only accurate response would be that there is no way to tell (Deny the Antecedent). I could also tell you "I have something in my hand that has vitamin K inside," and then ask you "Is it a blue jay?" In this case, the accurate response would be that there was no way to tell (Affirm the Consequence). And, finally, I could tell you "What I have in my hand does not contain vitamin K," and then ask you "Is it a blue jay?" You could be certain that your answer of no was correct (Modus Tollens).

Only Modus Ponens and Modus Tollens represent true deductive reasoning because they are the only instances in which an indisputable truth is possible. Written as an equation, with the letters above the line representing the premise and the letter below the line representing the conclusion, all four syllogisms are shown as equations in Figure 1.

| **Modus Ponens** | **Modus Tollens** | **Deny the Antecedent** | **Accept the Consequence** |
|---|---|---|---|
| **P ➔ Q** | **P ➔ Q** | **P ➔ Q** | **P ➔ Q** |
| **P** | **~ Q** | **~ P** | **Q** |
| **Q** | **~ P** | **No way to tell** | **No way to tell** |

*Figure 1.* Graphic representation of four deductive syllogisms.

These abstract formulae assume that once one makes accurate inferences (e.g., Modus Tollens) one can do so for any *P* or *Q*, but it turns out that deduction is highly influenced by context. For example, deductions with permissions are easier than with causal statements (Cheng & Holyoak, 1985). One might assume that deductions embedded in a highly organized theory-based domain would be easier because of the conceptual and semantic framework provided. Therefore, it is of interest to examine deductions in the domain of natural kinds.

Although Piaget claimed that deduction skills don't require context, the literature has shown otherwise for both children and adults (Johnson-Laird, 1995; Wason & Johnson-Laird, 1972; Wason, 1995).

### *Inductive Reasoning*

While deduction is used to draw an indisputable truth by reasoning, for example, from general to specific, induction is a probabilistic route to the truth because it can never claim absolute certainty. Induction uses the ability to recognize patterns, form conjectures based on these patterns, and reason from specific to specific or from specific to general. It takes a generally known fact or pattern and concludes that this fact can be assumed to be correct in other similar situations.

For example, if we know that the heart is a muscle that pumps blood through the body to keep it alive, and we also know that our dog has a heart, then it is reasonable to assume that other living dogs in the neighborhood also have hearts. By extending this assumption to the neighborhood cats, squirrels, chipmunks and rabbits, we are applying inductive reasoning to make a conclusion about the biological insides of the mammals in our sphere of knowledge. Inductive reasoning allows us to make reasonable conclusions about natural kinds that may be unfamiliar because of the rich generalizability of anatomical properties across biological categories. By using inductive reasoning we take specific pieces of information and use them to make general assumptions that will never yield absolute certainty. What permits these inductions is a coherent theory of a content domain such as natural kinds.

## *Categorization Theories*

The type of category (e.g., natural kinds) is only one factor that influences inference. The categorization model applied by the organizer also makes one type of inference easier or more difficult than another does.

Categorization is a mechanism that we use for sorting, storing, eliminating, retrieving, and extending information. Categories, such as natural kinds, allow us to organize diverse information into hierarchical cohesive groups that share similar characteristics by using specified criteria to define the relationship between instances as they exist in space and time. Three theories of how categories are utilized to organize information are described in the literature (Keil, 1989; Murphy, 2002; Rosch, 1975; Scholnick, 1999). They are classical categorization, semantic categorization, and concepts as theory. Key differences exist among these category theories. First, they differ in how the reasoner conceives the rules for categorization and applies them to members of the category. Second, they differ in the types of reasoning that can be used to determine category membership. Third, they differ in the types of within category levels that are applied (e.g., basic, subordinate, superordinate). Finally, they differ in the type of concepts that anchor the theory.

*Classical Categorization*

The classical categorization defined by Aristotle is a conceptual system based on the use of ontological categories, the most basic of which are physical objects and events (Carey, 1985). It is a categorization methodology that is defined by its use of a syntactic rule (Scholnick, 1999) "all and only." Members of a category all have the specific criteria defined by a set of rules. In addition, only members of that category meet the specified membership criteria.

For example, in the category of mammals, all members of the category defined as mammal must meet specific physical criteria. They nurse their young, have hair, and are warm-blooded. To be a member of the category all members must meet all of these physical criteria.  These rules, in this case physical attributes, are considered pieces of information or predicates that describe a characteristic that can be attributed to category members.  For example, "has hair" is a predicate that describes a necessary characteristic for category membership. In addition, only members of this category have this constellation of physical attributes.

By applying the logic of "all and only" you are either in the category or not, but never in-between.  Borders are crisp within this category schema. One of the hallmarks of classical categorization is the clear-cut categorization produced by the category inclusion rules.  With the use of the "all and only" rule structure, something either is or is not a member of the category and the person structuring the category either does or does not know the rules of the category and the necessary information about the instance to be categorized.

This type of categorization encourages deductive reasoning, but not inductive reasoning.  There is no place for probabilistic induction because there is no place for uncertainty.

*Semantic Categorization*

Rosch (Mervis & Rosch, 1981; Rosch, 1975; Rosch & Mervis, 1975) has suggested another categorization model based on semantics and observation.  While a defining feature of classical categorization is the rule of *all and only*, which necessitates sharp boundaries, the semantic categorization model proposes that category membership of biological instances is a more graded and probabilistic one with fuzzy boundaries and unequal levels of property representativeness among category members.  This model does not postulate sharply defined categories.

Instead, a majority of category members possess a cluster of features that are the same, but a small number of members require closer inspection to confirm their category membership because they have one or more, but not all of the properties in the cluster. In contrast, others might have all. Within the category of mammals, a cow has all the properties we associate with the mammal class, but whales and bats are also mammals. In addition, both the penguin and the house sparrow are members of the category *bird,* but the house sparrow exhibits characteristics such as "wings used for flying" that are more common in the majority of biological members of this category than the penguin whose wings are used for swimming, thus the sparrow is a prototype for a bird, not a penguin.

Both of these examples represent instances in which the majority of category members have a cluster of similar properties that identify them as category members. By using this cluster, and allowing for exceptions rather than applying hard and fast rules, category membership becomes probabilistic and therefore makes induction a necessity and deduction an impossibility.

This system of categorization is also one in which learning is done by induction. It is proposed that the child observes the natural world and starts to sort biological instances first by prototypical exemplars (e.g., sparrow) and then uses this exemplar to make inductions to other category members. Rosch proposes that simple features, such as shape, provide the first salient features for category delineation. Shape similarity makes it much easier to label as birds those instances that are more similar to house sparrow than penguin, further emphasizing the fact that a common characteristic of birds, "with wings that fly" is more common to some members than others and that some members of the category exhibit this trait, but not all. Additionally, within the category of bird, some (typical) exemplars of the category will possess the most number of similar characteristics, while other members will contain progressively fewer.

By using semantic categorization, learning is always done by induction, never deduction. In this model, the categorizer gains information from the environment by observing instances and making inductive associations about salient characteristics. Basic information may be presented by the child's social environment, but it is the child who begins to use induction to place other generally similar biological instances into category structures.

Categorization competency is based on the reasoner's frequency and depth of experiences with category members. It is assumed that others in the environment are exposing the child to experiences and exemplars that emphasize primary attributes. Exemplars are assigned the most basic perceptual attributes first (color, size) and additional information is added as the child matures. Because this presupposes that the child is getting information directly from the environment, this type of categorization is considered culturally influenced. It is proposed that the child takes in all information that he/she is exposed to and then begins to sort it by looking for possible similarities. Rules are not strictly applied and category boundaries are fuzzy and shifting.

This categorization model assumes that categories are defined by their members rather than by predetermined rules.

*Concepts as Theories*

The third category schema is "concepts as theories." This theory-based categorization, applied primarily to the natural kinds categories and commonly referred to as essentialism, suggests an intuitive understanding of something unseen within a natural kind that makes it what it is. Whereas classical categorization is restricted by a formula, theory-based categorization allows induction and is not restricted to perceptual appearance similarity or domain specific knowledge. Previously it had been assumed that young children could only categorize by external appearances as opposed to adults who appear to categorize by a more complex series of theoretical notions. "Concepts as theories" endows even young children with a grasp of essences.

With essentialism, category members are defined by their essence, which is a common, unseen property they all possess and which defines what they are. Categorization hierarchies are developed by the individual using both observable and unobservable features of the natural kind. The reasoner is not expected to be able to describe or even know what the essence is, but instead is just required to believe that it exists (Gelman, 2003). This lack of knowledge is sometimes referred to as placeholder essence (Medin & Ortony, 1989). Essentialism comprises a skeletal conceptual framework (Gelman, 1990; Gelman, 2003, 2004; Gelman & Wellman, 1991) that is flexible and guides the reasoner to further knowledge acquisition.

For example, mammals will have hair (observable) and be warm-blooded (non-observable). These features are the direct result of what is understood as the essence of the category member. Because some of these criteria are unobservable, the reasoner applies inductive strategies to novel instances to determine the appropriateness of category inclusion using a theory that all members of a category share a particular essence. In the case of living things (a natural kind) versus artifacts, which are not natural kinds, all living things contain something that allows them to be alive (e.g., organs, blood).

The importance of this type of categorization scheme is that it encourages inductive reasoning, producing inferences and generalizations about subsequent class members. But it also should promote deduction because there is an assumed common essence that determines category membership.

Each of these theories starts with the assumption that the categorizer will take information and organize it into categories that make sense to the organizer. They also assume that within those categories, levels of organization will emerge based on the frequency and similarity of the criteria that link members of a class.

*Category Levels – Basic, Superordinate, Subordinate*

Within each category structure, there is the potential for basic, superordinate and subordinate category levels. These levels are defined by the extent to which class members share commonalities, and the extent to which the category is distinct from other categories.

*Basic Level*

Taken any group of biological instances, according to Rosch, the basic category level is that which is considered most accessible because it has optimum coherence as well as distinctiveness. It is defined as the most inclusive where members have " a significant number of attributes in common, motor programs that are similar to each other, have similar shapes and can be identified by averaged shapes of member of the class" (Rosch, Mervis, Gray, Johnson, & Boyes-Bream, 1976).

For example, if my categories are flowers, tulips and parrot tulips, the basic category is tulips. This is the category which contains a reasonable number of commonalties that make tulips recognizable as tulips, yet distinct from other flowers, that is, most of us can identify a tulip from other flowers because it is reasonably distinctive from other kinds of flowers such as roses or carnations. Basic categories as defined by Rosch et al. (1976) are the earliest categories sorted and named by children.

*Superordinate Level*

The category of flowers is the superordinate category because it has high distinctiveness and low commonality. There are many plants that are members of the category flowers, so there are not many commonalties, but there are numerous ways in which the members of this category differ from members of other superordinate categories like animals.

*Subordinate Level*

The category of parrot tulips represents the subordinate category level. Members of this category contain the most number of commonalties among themselves, but they are hardest to distinguish from other varieties of tulips.

*Property Inheritance*

Figure 2 shows a graphic representation of these levels using circles with varying degrees of specificity. The superordinate level is labeled with the number 1 because it consists of all circles and only one feature defines it.  For this example circles are defined as “a closed plane curve every point of which is equidistant from a fixed point within the curve” (*Merriam-Websters*, 1993). Any circle of any size or any color can be a member of the superordinate level. The members of the class of circles can be heterogeneous.  The basic and most accessible level is labeled 1, 2 because it is defined by both shape (1) and color (2) and consists of red circles.  As long as the circle is red, it can be any size and still belong to the basic level. Note that there are two commonalities defining the class.  Finally, the subordinate level is labeled 1 (shape), 2 (color) and 3 (size).  For a circle to be a member of this level it must be large and red, so there are many properties that define the class but the classifier must pay attention to all three properties to differentiate these circles from other varieties.

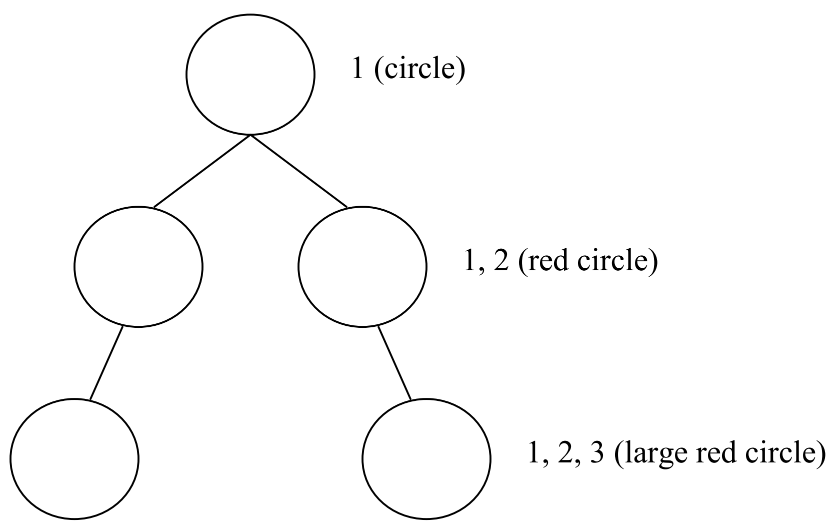


*Figure 2.* Diagram of property inheritance for superordinate, basic and subordinate levels.

Note that there is a relationship between the three classes, “1”, “1, 2” and “1, 2, 3”. The classes lower on the tree diagram inherit the (shape) property of the superordinate class, and the subordinate class inherits the shape and color of the basic class. In computer science this state of affairs might be described as class “1” is the mother of class “1, 2”. The analogy is to biological inheritance.

Natural kinds usually present a more varied picture than colored circles, where reasoners must confront biological inheritance in addition to perceptual similarity when making decisions. To examine this, Springer (1992) tested children between the ages of 4 and 8 to determine if they would favor kinship properties over visual similarity. In these studies, children were presented with a triad of animals, for example a large horse and two smaller horses, one of which looked like the larger horse but the other did not. The child was told that the dissimilar horse was the ‘baby’ of the large horse and that the similar horse was not a member of the same family. Children were taught that the large horse had hairy ears and then were asked which smaller horse would also have hairy ears. It was found that children were more likely to overlook perceptual similarity and instead invoke a kinship strategy saying that the dissimilar, but biologically related horse would share a biological property such as hairy ears. While children were not always able to provide biological reasoning for their choices, this study suggests that they are beginning to use kinship and biological inheritance as a marker for making inductive reasoning choices.

The reasons to consider category level are threefold. First, basic categories are more accessible. By definition, they are the ones that the reasoner considers most familiar. Second, inductions are easier among categories that are less distant in level from one another.  That is, it is easier to make the inductive leap from poodle to greyhound because both animals belong to the same basic class (dog) than it is from poodle to sheep where they belong to the same superordinate class (mammal). Thus, it might be assumed that category level affects ease of induction and potentially deduction.

Finally, while inductions are category driven, they are also based on probabilistic notions when examining natural kinds.  While Figure 2 presents levels with discrete parameters, natural kinds can present a more varied array of options that the reasoner must consider.

The following section will show that age, knowledge, and frame or task, in addition to underlying theoretical notions, can affect the reasoner's use of levels, including shifting the basic level, as knowledge becomes more complete.

### *Previous Research Findings*

The remainder of the chapter is organized into five sections. The first section is a review of concepts as theory findings and the implications of this approach to conceptualization and reasoning.  The next sections include factors influencing reasoning, such as category levels, category labels, argument strength and the implications of culture.

As discussed earlier, natural kinds are a category of living organisms consisting primarily of plants and animals.  They possess things inside of them that provide information about their functioning. They also possess both observable and unobservable properties that are consistent across class or kind.  These traits and characteristics are passed down from generation to generation imbuing progeny with similar characteristics. Finally, these characteristics maintain their consistency over time. Whatever characteristics define a parrot tulip will be the same today as they are tomorrow.

The unobservable properties have been labeled an "essence" by Gelman and her colleagues. This essence is defined as the "underlying reality or true nature, shared by members of a category, that one cannot observe directly, but that gives an object its identity and is responsible for other similarities that category members share" (Gelman, 2004).

The ability to utilize inductive reasoning combined with our ability to categorize input allows us to make probabilistic inferences, thereby circumventing the need to learn everything from scratch about a new instance. The research done for this study seeks to understand what might affect an individual's ability to make inductions about natural kinds and what underlies induction in natural kinds. Is induction driven by a single theory, such as essentialism, or is it a function of knowledge, age, and task or frame? If it is a function of these factors, can a shift in age or knowledge account for children's performance on particular tasks? These are the questions that this research strives to answer. A review of previous research will lay the groundwork for understanding what is already known and how those results help to explain the results found in this research.

*Concepts as Theories*

By the mid 1980s, Gelman and others (Gelman 1988; Gelman & Markman, 1987) had begun to take a close look at young children's use of induction in natural kinds. Gelman and Markman's 1987 study tested whether children would expect category members to share an unforeseen property. As stated before, this essence is not something that can be seen or touched, but instead it is an unseen force that represents life, growth, and certain innate characteristics that separate biological entities from artifacts and from each other. For example, an essence would be what makes a lion “lion-like.” By understanding that this essence exists, Gelman postulates that the young child is able to categorize seemingly different biological entities within the same category. For example, although a poodle and a german shepherd do not share the same appearance, a child will recognize both as dogs. Concomitantly, individual people may vary in skin color, body size, or hair texture, but still be recognized as people. But the quandary is in knowing if the child is applying an essentialist theory and understanding of something that is non-concrete and unseen or simply using perceptual clues combined with previous knowledge as the pathway for determining category membership.

To test this notion, in one experiment researchers (Gelman & Markman, 1987) showed 3- and 4-year-old children a picture of a black cat with a white stripe as the target clue. They were also shown other pictures: a black cat with a white stripe (same category, similar markings), a cat that looks white (same category, different appearance); a skunk (different category, similar appearance) and a dinosaur (different category, different appearance). Children were then a taught a property about the target clue (i.e., cats can see in the dark) and were asked if that information also applied to the other animals in the task. Results showed that children at this age thought that the two cats saw in the dark, but not the skunk or the dinosaur, proving that they could use category information and not simply appearance to make inductions. Their young age showed that they were unlikely to be depending on formal education or scientific knowledge.

Additional studies (Gelman, 1988) showed that as children age they also begin to incorporate knowledge into their judgments of biological kind category. Two of the questions that this study sought to answer were how children limit their use of induction and how these patterns change as the child ages. To test these notions, pre-school and second grade children learned something about a natural kind (this rabbit likes to eat alfalfa). They were then shown four pictures; same category and appearance as the target (brown rabbit), same category, but different appearance (white rabbit), same superordinate category (dog) and unrelated category (telephone). Children were asked to decide which of other items with varying degrees of similarity to the target clue (a rabbit) also liked to eat alfalfa. As one might expect, responses from 4-year-olds varied from those of second graders. Younger children did not place as many constraints on their use of induction, however their choices did reflect the fact they were more likely to generalize to a similar target clue. The second graders showed the same type of responses; however the important conclusion with older children was that they began to show different expectations between natural kinds and artifacts. According to Gelman they began to expect that natural kinds would have more similarities in reference to internal parts and behavior than they expected from inanimate objects. The author postulates that this is directly related to children's increased scientific knowledge. That scientific knowledge is then used to augment underlying theoretical notions that children are using, such as essentialism.

What may be most important in these results is that if children are using their scientific knowledge to separate artifacts from natural kinds, it may also be possible for them to use scientific knowledge to influence their thinking with natural kinds categories.

Additional questions about children's ability to overlook outward appearance were studied by Gelman and her colleagues (Gelman & Coley, 1990; Gelman & Markman, 1986), with results indicating that children were using a conceptual framework that gave credence to underlying unseen essences. In the Gelman and Markman study, perceptual similarity was pitted against category membership. Four and 5-year-olds saw a picture of a tropical fish. They were told that these were fish and that they breathed underwater. A picture of a dolphin, bearing a striking resemblance to members of the basic category "fish," was also shown to participants. They were told that it was a dolphin and that it popped out of the water to breathe. Children were then shown a picture of a shark that closely resembled the dolphin and were told that it was a fish. They were asked to decide how it breathed. Results showed that children did make correct inferences based on category, and not perceptual similarity, and assumed that the fish could breathe underwater, but the dolphins could not.

Gelman and Coley's 1990 study modified this experiment to determine if even younger children would also overlook perceptual similarity. In this oft-cited study, 2-year old children were shown a picture of a creature typical of a category that they were familiar with, the bird category. Four other pictures were also presented. For the bird category, children saw a bluebird and a dodo bird. They were also shown a stegosaurus and a pterodactyl (a winged dinosaur that looks like a bird). Two of the pictures (bluebird and pterodactyl) resembled the target category. Children were told that birds lived in a nest. In the first condition of this experiment, the label of either dinosaur or bird was given to each picture. In the second condition, labels were not given. For both conditions, children were then asked which animals might also live in a nest. Children were accurate on pictures where the animal was the prototype of the category (e.g., a sparrow), but needed labels to be accurate on pictures of atypical birds (e.g., dodo bird). This showed that perceptual clues were important. However, in some cases language clues were necessary. An expanded review of the importance of labeling will be presented later in this chapter; however it should be noted that language refined their inductive skills in this task.

Children's attention to non-obvious properties and their ability to understand the importance or privileged status of these properties were also tested by Gelman and Wellman (1991) with 4- and 5-year-old children to understand exactly what types of information children might have access to when making inductive inferences. These researchers hypothesized that insides and essences, those unobservable qualities, were important concepts for children to grasp if they were to overlook observable characteristics. Children were asked if a natural kind would retain its identity (would it still be a dog) if its *insides* were removed (i.e., "What if you take out the stuff inside of the dog, you know, the blood and bones and things like that and got rid of it and all you have left are the outsides?") or its outside covering (i.e., "What if you take off the stuff outside of the dog, you know, the fur and got rid of it and all you have left are the insides?"). In this experiment children considered the *insides* more relevant than the *outside* in retaining natural kind identity. Children were not expected to be able to describe the inside characteristics or its essence or to even call it an essence. The researcher's only expectation was that children would be able to conceptualize the idea that *something* inside of a natural kind was responsible for its continued membership in a particular category. When children know that something internal causes category membership, but are unable to name it, it is called the placeholder notion (Medin & Ortony, 1989).

Gelman and Wellman (1991) argue that while children may have rudimentary scientific understanding that allows them to know that there is something inside a natural kind, they do not have access to knowledge that would tell them that the insides are necessary for functioning and identity. Consequently, it would also seem that age and experience, again, are factors that must be considered as important features in children's inductive reasoning.

While much has been done to try to prove that children use essentialism in inductive reasoning, there have also been detractors who describe flaws in the essentialist approach. Critics focus on the kinds of beliefs the child possesses, the possibility there are developmental shifts in those beliefs and the role of culture and context in affecting the development and use of essentialist notions.

It has been suggested that essentialism includes an individual's belief that there are natural kind categories and the belief that there are unobservable "essences" that are responsible for observable characteristics that place natural kinds into specific categories. However, Strevens (2000) has suggested that essentialism can be explained with a "minimal hypothesis" whereby an individual simply assumes that kind membership accounts for observable characteristics and causal laws between kind members rather than a causal essence within a kind that forms the basis for induction. Carey (1999) argues that knowledge acquisition can change children's theoretical beliefs. She cites the work of Inagaki and Hatano (1996) describing the theory change that children make by the age of five years when, according to these researchers, children begin to unite all living things (plants and animals) into one category as they understand more about what it means to be alive including the necessity for food and water.

And, Malt (1994) suggests that natural kind categorization is very much influenced by desires and social context. In one study participants were given a list of items (pond water, tea, bath water) and asked to determine the amount of water in liquids called "water" (pond water) versus those not called water (tea). It is suggested that while essentialism plays a role in reasoning about water, source, location and function also influence individual's categorization. Choices varied and responses did not necessarily reflect that $H_20$ represented the essence of all things that might be considered water. While water is a natural kind, but not a creature as we have been discussing, it still highlights the importance of frame and knowledge and their joint impact on categorization.

In particular, Rothschild and Haslam (2003) suggest that there may be a difference between pragmatic essentialism and naturalistic essentialism. A pragmatic essentialism would change based on circumstances and knowledge. This assumes that an essence is not an independent structure that exists within a natural kind.

What is important for this paper is the understanding that essentialism is not necessarily an overarching theory that can be applied in a blanket manner. Others have suggested alternatives that may account for children's beliefs and their application in inductive reasoning. Even Gelman, in recent years (2003), has suggested that essentialism is a "framework for organizing our knowledge of the world." She does speculate that adults may continue to utilize a form of essentialism, but that it may be modified with age.

It would be seem reasonable to assume that the framework is adjusted as knowledge is accumulated and needs and desires shift.

Since Rosch (1975), Carey (1985) and Gelman (1988) first suggested that children's conceptual frameworks might develop differently than was previously thought, much research has been done to investigate these shifts and their implications for development. Two task factors that might affect use of essentialist reasoning are category levels and category labels.

*Category Levels*

While children's underlying beliefs provide a guide to their categorization and use of induction, there are other factors that also need to be examined and understood. One of those is the level at which children access information.

As stated earlier, categories can be broken into three levels; basic (the most accessible), superordinate (the most encompassing), and subordinate (the most number of similarities between the group and the fewest differences from contrasting classes). Basic categories provide the most amount of information to the reasoner and also possess the "highest category cue validity," which makes them the most differentiated from one another (Rosch, Mervis, Gray, Johnson & Boyes-Breahm, 1976). Superordinate categories can be subdivided into basic categories, which in turn can be subdivided into subordinate categories (See Figure 2). In this schema, dog would be considered the basic level, dalmatian would be the subordinate level and mammal (canine) would be the superordinate level.

In particular, the question is whether the descriptive level of the category determines the ease of induction. Building on the idea that categorization might be influenced by specific knowledge, Waxman, Lynch, Casey & Baer (1997) examined the possibility that pre-school children might be able to extend their knowledge of basic level categories to subordinate categories and that this extension would be facilitated by teaching children contrastive knowledge about similar subordinate members of a basic level. In this experiment, one of the basic levels that children were tested on was butterflies. All children were taught about blue butterflies and white butterflies. Half of the children were taught that blue butterflies ate fruit and white butterflies ate mustard plants. This was considered contrastive information. The second group of children was taught that blue butterflies slept standing up and that white butterflies laid eggs shaped like pears. This is considered non-contrastive information. Both groups were then asked if fritallaries (a type of butterfly) ate violet flowers. Results showed that children who had been taught the contrastive information were more likely to agree that fritillaries ate violet flowers (thereby using induction to make inferences at the subordinate level), than those who had been taught non-contrastive information. In this case, the type of knowledge influenced induction.

This experiment provides two important pieces of information. First, it tells us that even very young children can make inductions from the basic to the subordinate level and not just across basic level categories. But more importantly, it shows that context (contrastive vs. non-contrastive information) can affect children's reasoning. These results lend credence to the idea that, while children may be using an essentialist theory, this theory can be affected by the context of the knowledge that they acquire.

The role of language and children's inference to category levels was also investigated in an early study (Gelman & O'Reilly, 1988). While the researchers sought to understand children's inclination to infer instances beyond surface appearances, results showed an age difference in children's use of inductive levels. In this case, preschoolers through second graders were taught that an apple had "auxim" inside. They were then asked if another apple, a fruit and an artifact would also have auxim. Inferences were drawn most frequently at the basic level (in this case apple), for younger children, while older children were also more able to draw inferences about the superordinate level (fruit). Again, these results showed that as children develop and presumably gain more knowledge they are more able to draw on taxonomic knowledge to make inductions. This shift would seem to stem from increased knowledge.

The importance of these studies is that it appears that knowledge and task both serve to influence inductive reasoning ability. In part, it has been shown that the ease with which children use induction depends upon the taxonomic level at which they are trying to reason and the knowledge to which they have access.

*Category Labels*

Category labels allow the individual to determine where certain instances fit into the hierarchical structure and what strategies might be most useful for induction. If we refer back to Figure 2, the label *circle* identifies the superordinate category, the label *red circle* signifies the basic category and the label *large red circle* designates the subordinate category. The labels provide us with information necessary to make other inductions.

By understanding and utilizing the role of property inheritance, the reasoner is able to use labels as a starting point for extending category inferences. As outlined before, whatever defining characteristic is possessed by the superordinate category (circle) will also be possessed by the basic and subordinate category, but distinguishing properties of the subordinate category of red circles, (large) do not define the basic category (red circle).

Yamauchi and Markman (2000) suggest that categorization is even more complex than originally thought with category labels and category features playing uneven roles under some circumstances. In a task where category labels and category features (similarity) were pitted against each other, category labels guided participants attention and ultimate inferences. This is consistent with early studies (Gelman & Markman, 1986) showing that category membership is not simply feature driven, but will also be influenced by common labels assigned to different items.

As pointed out by Markman and Ross (2003), category development is a complex process, not dependent on any one particular learning strategy and in the past research has not always addressed this complexity with the attention it deserves. They note that labels call attention to properties and entities and provide powerful information for placing kinds in specific categories. For example, knowledge of a label (something is a giraffe) would encourage class inclusion strategies by providing a specific natural kind label. On the other hand information about a feature (something has a long neck) would encourage a partonomic relation because we only have information about part of the instance (the neck). In the second case there may be many things that have long necks (e.g., giraffes, ostriches, and brontosauruses). The studies of labeling (Yamauchi & Markman, 2000, Gelman & Markman, 1990) emphasize the importance of context in accessing the knowledge base or conceptual theory that undergirds induction.

While much of the research described in the previous paragraph was done with adults, Gelman and Heyman (1999) showed similar label stability with their study of noun versus verb predicate labels in children 5- and 7-years-old. In this study children were given two options for labelling an item. They were told that “Rose eats a lot of carrots.” They were then told either “Rose is a carrot eater” or “She eats carrots whenever she can.” Both age groups of children agreed that the first label, rather than the second, presented a more stable condition.

This example emphasizes the point that Markman and Ross (2003) have made noting that even small word changes in labeling may affect the use of inductive reasoning and in the worst case, affect the outcome of study results in an unforeseen fashion. It is important to keep in mind that an individual’s use of a category as the basis for induction may be affected by multiple variables and each of these variables may carry different weights, even for different individuals within different cultures.

*Argument Strength*

While aspects of categories, such as labels or features, affect category development and use, argument strength also affects that way in which we apply inductive reasoning strategies. Arguments contain one or more premises and one conclusion. The premise is the basis for the argument and provides information (hawks have sesamoid bones). The conclusion is the answer that is derived from the premises (all birds have sesamoid bones). If the reasoner feels that the argument is strong they are more likely to use induction to derive a conclusion than if they feel the argument is weak.

Researchers have identified numerous types of arguments with varying degrees of strength that might influence the use of induction. Osherson and his colleagues (Osherson, Smith, Wilkie, Lopez, & Shafir, 1990) tested the strength of categorical arguments by changing the premise and conclusion statements for particular arguments. Each argument contained a specific natural kind category and a novel property. In each case arguments were pitted against each other to determine their reasoning strength.

One example, referred to as premise monotonicity, is shown in the set of arguments below. Set A is the more inclusive set of premises because it mentions more birds, thus, it yields more strength than the less inclusive set (Set B).

Set A. Hawks have sesamoid bones.
Sparrows have sesamoid bones.
<u>Eagles have sesamoid bones</u>
All birds have sesamoid bones

Set B. Sparrows have sesamoid bones
<u>Eagles have sesamoid bones</u>
All birds have sesamoid bones.

In premise typicality, Set A, containing the more typical bird (robin) is judged to be stronger than Set B containing the Penguin.

Set A. Robins have a higher potassium concentration in their blood than humans
All birds have a higher potassium concentration in their blood than humans

Set B. Penguins have a higher potassium concentration in their blood than humans
All birds have a higher potassium concentration in their blood than humans

These experiments looked not only at similarity and typicality in arguments (Sets A and B), but also diversity in arguments. Osherson et al. (1990) reported that diversity of exemplars within an argument might also strengthen it. The example below is considered premise diversity. Set A below is a stronger argument than Set B. In this case, lions and giraffes are two natural kinds with a greater distance between them than lions and tigers and should provide the reasoner with a greater diversity or coverage from which to build their inductive reasoning.

Set A. Lions use norepinephrine as a neurotransmitter
Giraffes use norepinephrine as a neurotransmitter
Rabbits use norpinephrine as a neurotransmitter

Set B. Lions use norepinephrine as a neurotransmitter
Tigers use norepinephrine as a neurotransmitter
Rabbits use norepinephrine as a neurotransmitter

Lopez, Gelman, Gutheil, and Smith (1992) utilized arguments similar to those used by Osherson et al. to determine if kindergartners, second graders and adults would apply strategies in ways similar to those reported. As expected, all age groups judged arguments with typical and similar instances to be stronger than ones containing atypical and dissimilar instances. Similarly arguments of typicality and similarity where the premise was either very typical of the category (robin is a typical bird) or the premise and conclusions were similar natural kinds (horse, zebra/donkey is stronger than horse, zebra/squirrel) were considered stronger.

What is of greater interest to us is that kindergartners did not utilize diversity in any form to differentiate argument strength and second graders only used it under certain circumstances. The authors claim this represents an orderly process in the development of the use of argument strength. For our purposes it suggests two possibilities. First is that the framework of any argument may affect the way in which it is utilized by reasoners of differing ages. But it is also possible that this represents the ability to make inductions across instances further apart in a hierarchy and kindergartners simply do not have the same ability to make inductions across instances farther apart in the hierarchy.

*Folkbiology*

One of the criticisms of the research described earlier in this chapter is that frequently participants are either undergraduate students or younger children who represent the middle and upper-class majority culture in America. While there have been studies done in other populations (Bailenson, Shum, Atran, Medin, & Coley, 2002; Choi, Nisbett, & Smith, 1997; Hatano, Siegler, Richards, Inagaki, Stavy, & Wax, 1993; Inagaki & Hatano, 1996; Medin & Atran, 1999), they do not represent the majority of reported results.

Folkbiology, which studies the intuitive theories held by people, seeks to remedy this situation by studying people in different cultures. This section of the chapter presents some of the results of folkbiology research that directly references inductive reasoning. These results are cause for rethinking the role that culture and experience play in the development of inductive reasoning. Specifically, they highlight the fact that knowledge and frame may influence inductive reasoning.

While the folkbiology literature reports slightly different terminology, for ease of reading, we will continue to use the category levels (basic, superordinate and subordinate) that we have used throughout this document. It is important to note that previous folkbiology research (Berlin, 1978) has argued that the subordinate (folk-generic) level is the most privileged in folkbiology as opposed to Rosch et al. (1976) who have shown that the basic level is the most privileged level for the population they studied. Thus, there is disagreement between disciplines. However, it has been suggested that this difference in privileged levels is a reflection of greater knowledge of natural kinds among certain populations. This research is discussed below.

In a study by Coley, Medin and Atran (1997), the question of privileged level in traditional societies versus industrialized urban dwellers and its import to induction were examined. According to Rosch (1975) the basic level is the most privileged level because of its high within category similarity, making it the most conducive to induction. It is the level above which substantial information is lost and below which little information is gained.

American college students were compared to the Itzaj Mayans, members of a traditional village in Guatemala, in a series of studies. Participants were told a piece of information about one level of animal or plant and were asked if that information applied to other levels. For example, “If all rainbow trout have protein A, how likely is it that all fish have protein A?” or “If all sharks have protein A, how likely is it that all fish have protein A?” Different appropriate natural kinds were used for each group of participants.

According to Coley et al. (1997), a “privileged level would be the highest or most abstract level at which inductive confidence is strong.” That suggests that the privileged level for the Itzaj would be the subordinate level and the privileged level of the American college students would be the basic level because the Itzaj were closer to working with plants and animals.

Study results were somewhat surprising. They showed that the subordinate levels were privileged for both populations. This type of result would be expected for a traditional society, but not the college students. The authors suggest that while the Itzaj may be basing their inductions on knowledge, the students were using both knowledge and implicit expectations, based on language, of what might be in a category.

It is also pointed out that possibly what was measured by Rosch as opposed to Coley et al. was different. In the Rosch experiment, participants were being asked to list features which required a certain level of knowledge. In the Coley study, individuals were told information (“If all rainbow trout have protein A, how likely is it that all fish have protein A?”) and then asked about their expectations. This experiment much more closely reflects that types of experiments that have been done in natural kinds studies.

According to the authors, Americans *expect* subordinate levels (folk generic – trout) to be the most useful for inductive reasoning. In other words, for urbanized individuals with little contact with nature, language and expectations may privilege a level and not necessarily knowledge. According to these results it would seem that the level at while knowledge is accessed is different, but the level at which induction is the strongest is the same.

There are two important notions from these results that deserve consideration. First, the authors suggest that one “basic” level for all people may be too simplified a notion. Second is that multiple factors may influence induction, in this case, natural kinds, including experience, knowledge and implicit expectations arising from category labels.

Researchers have also been interested in knowing if the anthropocentrism described by Carey (1985) would be found in other cultures, i.e., that humans were the prototype for inductive generalizations. Ross, Medin, Coley and Atran (2003) suggested that cultural and experiential differences might affect children’s views of the natural kinds. Because Carey’s original work was done with urbanized children, Ross et al. studied majority urban children, majority rural children, and Native American children (Menominee) using a projection task similar to Cary’s task, in other words, if X has an omentum, does Y?

Children in three age groups, kindergarten and 1st grade, 2nd and 3rd grade and 4th grade, from three different cultural and experiential backgrounds (urban majority, rural majority and rural Menominee), were tested. The protocol consisted of five different bases (human, wolf, bee, goldenrod and water). There were also 16 target objects, for example human, bear, eagle, trout, milkweed and pencil. Children were asked to project five unknown properties, like andro or gluco. They were taught that one of the bases contained a property and then would be asked if the targets also contained that property.

The overall results showed that both majority culture groups showed some anthropocentricism, with rural majority children showing a decrease as they aged. In contrast, none of the Menominee children showed this tendency, even at the youngest ages. This would suggest that both age and experience might affect children's reasoning. Also of note is the fact that Menominee children frequently gave ecological reasoning for some of their responses. For example, when generalizing from bees to bears, they justified this by saying that "a bee might sting a bear, or a bear would eat honey."

These types of comments are of interest because they suggest that more than just biological similarity may influence children when they make inductions in biological kinds and that these types of justifications are based on experience and knowledge.

But most importantly, the study showed that relative expertise and interaction with the environment, as opposed to limited knowledge (going fishing as opposed to reading a book about fish), may have substantial influence on conceptual development. The authors suggest that when exploring cognitive differences, it might be wise to study U.S. college populations not as a baseline, but as a group that provides information reflecting an individual's conceptual development with potentially limited natural kinds input.

Disendruck (2001) has also studied essentialism with children in Brazil. He replicated an earlier study (Disendruck, Gelman, & Lebowitz, 1998) in which children were shown pictures of typical and atypical animals of the same species and were taught that either two animals had the same internal properties (bones and muscles) or that they shared the same external properties (live in the same zoo). Children were then taught labels for these animals (e.g., "This is a snake, it is a zava" or "This is not a snake, it is not a zava"). The premise of this research was that if children were using essentialism, they would be more likely to infer that animals sharing internal properties and being from the same species might also share a common label. In fact, this turned out to be true.

But the other component of this experiment and the reason for repeating it was that in 2001 the study was done with Brazilian children from two different socio-economic groups, middle class and shantytown. Results showed that there was no difference in reasoning between the two groups.

However, I would argue that this study is not substantially different from those done with children in the United States. While the socioeconomic status is different, their interaction with nature does not vary substantially from other children in the U.S. who have been tested. A more definitive test of cultural influence would be between children whose knowledge base differs not only at the level of knowledge, but also experience and interaction with nature.

It is for these reasons that the importance of comparative research cannot be underestimated. Coley (2000) suggests that we need to study adult endpoints to understand children's development and we need to study all of this within different cultures.  Clearly, if age, biological knowledge, the way in which that knowledge is obtained (experience versus classroom) and the context of the task are to be considered, we need to reconsider the way in which we test children to discover if they do use essentialism in inductive reasoning about natural kinds.

I would agree with Coley (2000) that we do not yet fully understand the confounds in research in inductive reasoning and that careful attention to knowledge, the way in which it is obtained, participant age and context of studies may all play a substantial role in our understanding of inductive reasoning.  The studies in this paper begin to address three of these variables; logical conjunctions, frame, and age.

# Chapter 2: Background Research

As discussed in Chapter 1, previous research has examined the child's understanding and knowledge of certain non-obvious general characteristics that would maintain life and support growth and reproduction in all animals (Gelman, 1988, 2003; Gelman & Coley, 1990; Gelman & Wellman, 1991; Simons & Keil, 1995). Utilizing this type of a causal theory it is claimed that even a 2-year-old can employ induction to make generalizations from one animal to another. If a child is taught that one animal has an omentum, they could infer that other categorically similar animals might also have an omentum. But what enables the child to do this? In an effort to examine some of the variables that might influence a child's reasoning, Scholnick, Hammond, and Fener developed an experiment to look at several important research questions.

To support any claim that the child is using an essentialist theory of natural kinds to make inductions it is important to determine, first, whether the child has an understanding of biological taxonomies. Is the child able to accurately categorize natural kinds into a taxonomy that would show an understanding that poodles are a subset of dogs and that dogs are a subset of animals and that animals are a subset of living things? If children can accurately categorize, is this understanding related to the type and extent to which the child makes inferences across natural kind categories? Finally, if biological concepts are embedded in a causal theory that enables inductions, this theory should also support deductive competence. Thus, one would expect linkages between categorization, induction, and deduction during development. The primary questions considered in the first study were:

1. What is the course of development of knowledge of biological categories?
2. What is the course of development of induction?
3. What is the course of development of deduction?
4. How are these three developmental skills related?

It was hypothesized that the level at which the child is able to make accurate categorical sorts constrains the extent to which the child is able to make accurate inferences about biological kinds. In other words, the child who can only identify dogs can only make generalizations across the category titled "dogs." Is the inverse also true? Will the child who is able to accurately categorize subordinate, basic, and superordinate categories of natural kinds also be able to make inferences across these categories if given information at the basic level? Moreover, if the ability to make inductive judgments exists and is theory driven, this theory should also be applied in deduction. Finally, what is the relationship between these three skills?

*Method*

*Participants*

Three age groups were tested for Study #1. The first two groups consisted of 24 7- to 9-year-olds ($M$ = 8.4 years) and 24 10- to 12-year-olds ($M$ = 11.4 years). Children who participated in the study came from several areas including the University of Maryland Summer Arts Program and neighborhoods in High Point, North Carolina; Silver Spring, Maryland; and Potomac, Maryland.

A third group was also tested. This population consisted of a total of 36 University of Maryland undergraduate students evenly divided between males and females (M = 19 years 1 month). All cohorts were evenly divided between males and females.

All participants or parents/guardians signed consent forms.

*Deduction Warm-up Task*

To assure that all participants were capable of both inductive and deductive reasoning and to familiarize them with the testing procedure, each participant was given two warm-up tasks. The first task tested deductive reasoning. During this task the subject was seated across from the examiner. On a table in front of the subject were two stacks of cards. One stack contained only cards with green backs. The second stack contained cards with purple backs and cards with green backs. The examiner held a separate set of both purple and green cards in her hand with only the backs showing. The stacks on the table were presented so that the subject could easily determine that only one of the stacks contained purple cards. The following instructions were given to each of the participants.

> This is a thinking game. Let me show you how it works. I have two stacks of cards. This stack (examiner points to the stack with only green cards) is where the green cards belong, but this other stack (examiner points to the stack with both purple and green cards) can have purple or green cards. Here are some other purple and green cards (examiner shows the subject cards that she holds in her hand) that were left on the table by someone else. Someone took some of the cards out of each stack. I want you to return the cards to the way they were before. Can you figure out which stack the person got the cards

> from? You know that if it's a purple card, it came from this stack (examiner points to the stack of mixed cards). Let's see if we can figure out where these cards came from or if there's not enough information to tell. Remember, if it is a purple card, it came from this stack (examiner points to stack of mixed cards).

The instructions read to the subject establishes the **P therefore Q equation.** "If it is a purple card (**P**) it came from this stack (of mixed cards) (**Q**)." The examiner asked a series of four deductive questions (MP, MT, DA, and AC) to determine if the subject understood and was capable of deductive reasoning. (See Chapter 1 for complete description of each deductive syllogism.)

For example, the examiner held up a purple card. She reminded the participant that "If it's a purple card, it comes from this stack" (pointing to the mixed stack of cards). She then pointed to the stack of only green cards and asked the participant if the card in her hand came from that stack with only green cards. If the participant understands deductive reasoning, then the obvious answer is no (Modus Tollens). The examiner would then hold up a green card, remind the participant again "If it's a purple card, it came from this stack" (pointing to the mixed stack of cards). She would point to the stack with only green cards and ask the subject if the green card in her hand came from that stack.

Because it is impossible to arrive at an absolute answer, the correct response can only be that there is no way to tell (Deny the Antecedent). If participants answered the first four questions correctly, the deductive warm-up was considered complete. The examiner had three card sets containing four cards each. She shuffled the cards within each set and also shuffled the three sets before each subject was seen. Participants were given up to 12 tries to master this task, and were given feedback if they answered incorrectly. All of the participants successively mastered this task within twelve tries.

*Induction Warm-upTask*

The same set of purple and green cards was used to perform the inductive warm-up task. The green target card was placed face down on the table. The subject saw only the back of the green target card on which there was a geometric design consisting of thin solid lines and thin dashed lines. The backs of the cards in the examiner's hand displayed geometric designs with varying similarity (and hence inductive "proximity") to the target card. The participant was given the following instructions.

> This card (the target card) has a circle on the other side. Some of these cards have a circle too (examiner is referring to the cards in her hand). Could you tell which has the circle without turning the cards over? Tell me which ones have the circle on them. We'll put those in the yes box. Which ones definitely don't have the circle on them? We will put those in the no box. Those for which there is not enough information to tell we'll put in the not enough information to tell box.

Each card from the examiner's hand was then individually placed next to the target card and the subject was asked to determine if there was definitely a circle on the other side of this card, if there definitely was not a circle on the other side, or if there was no way to tell. These response options were given to the participants in random order. Cards were placed in the appropriate marked boxes (yes, no, no way to tell) depending on the subject's response and left there to be recorded on the score sheet after all tasks were completed.

Because induction is based on probabilistic inference, there would be no reason to eliminate any participants based on their responses to the induction warm-up task.

*Main Tasks – Deduction/Induction*

After the warm-up tasks were completed, participants were given the primary set of tasks that included both inductive and deductive problems. Two different sets of cards, with intermingled inductive and deductive questions, were used for this test. The subject saw only the back of each card, which was blank. All cards were shuffled between participants to address order and stimulus effects. Participants were given the following instructions

> Now we need to sort some other things. Each time I will tell you a clue and then ask you to sort things. Can you use the clue to help me figure out where to put the cards? (The examiner gestures to the yes, no and no way to tell boxes used earlier.) I have to warn you that sometimes the clue will tell you the answer and sometimes the clue just doesn't give enough information. Let's see if we can figure out where these cards belong or if there's not enough information to tell.

Verbally presented induction problems included: (a) a clue, (e.g., "If it is a blue jay, it has vitamin K inside"), (b) additional information, (e.g., "This is a parrot"), and (c) a question, (e.g., "Does it have vitamin K inside?"). Reasoners could respond by answering yes, no, or no way to tell. The 16 induction problems were divided into two sets. Each set was anchored by a different primary clue (blue jay or poodle). Participants began with poodle or blue jay based on a previously assigned code. There were a total of eight secondary queries for each primary clue. Four of these secondary queries were couched in generic terms such as “another bird,” while the additional four used more specific exemplars such as “parrot.” All of the secondary clues were of varying categorical distance from the primary clue. Tables 1 and 2 display this information in detail.

Table 1

*Inductive Reasoning Specific to Specific*

Primary Clue: If it’s a blue jay, it has vitamin K inside

| Type of Level | Categorical Distance | Secondary Clue and Questions |
| --- | --- | --- |
| Same Basic Level | Another bird | This is a **parrot**. Does it have vitamin K inside? |
| Same Superordinate Level | Another animal | This is a **horse**. Does it have vitamin K inside? |
| General Level | Another living thing | This is a **rose**. Does it have vitamin K inside? |
| Artifact | Non-living thing | This is a **chair**. Does it have vitamin K inside? |

Table 2

*Inductive Reasoning Specific to General*

Primary Clue: If it's a blue jay, it has vitamin K inside

| Type of Level | Categorical Distance | Secondary Clue and Questions |
|---|---|---|
| Same Basic Level | Another bird | This is another bird. Does it have vitamin K inside? |
| Same Superordinate Level | Another animal | This is another animal. Does it have vitamin K inside? |
| General Level | Another living thing | This is another living thing. Does it have vitamin K inside? |
| Artifact | Non-living things | This is something. Does it have Vitamin K inside? |

Four deductive problems were generated from each primary clue (8 total deductive problems) by changing the (a) secondary clue and (b) query to produce Modus Ponens (MP), Modus Tollens (MT), Deny the Antecedent (DA), and Affirm the Consequence (AC) (e.g., "This is not a blue jay. Does it have vitamin K inside?"). Table 3 lists the deductive clues and answers for one set of deductive problems.

Table 3

*Deductive Reasoning Task*

Primary Clue: If it's a blue jay, it has vitamin K inside

| Deductive Syllogism | Secondary Clue and Question | Correct Answers |
|---|---|---|
| Modus Ponens (MP) | This is a blue jay. Does it have vitamin K inside? | Yes |
| Deny the Antecedent (DA) | This is not a blue jay. Does it have vitamin K inside? | There is no way to tell |
| Affirm the Consequence (AC) | This has vitamin K inside. Is it a blue jay? | There is no way to tell |
| Modus Tollens (MT) | This does not have vitamin K inside. Is it a blue jay? | No |

Deduction and induction problems with the same primary clue were intermingled to achieve the desired embedded task. The cards for both induction and deduction queries appear the same to the subject and the order of the questions were randomized. Both induction and deduction tasks were repeated using the same format, but with a different primary clue and questions (e.g., "If it's a poodle, it has biotin inside. This is a german shepherd. Does it have biotin inside?").

*Categorization Task*

The final task consisted of a series of 16 cards that contained pictures of the living and non-living items in the previous task in addition to other items in each of the categories. The participant was asked to sort the cards by the following four categories: birds, dogs, animals and living things. The order in which the participants were asked to sort by category was randomized.

*Relevant Results from Study #1*

Analysis of the data provided results germane to the initial questions.

1. What is the course of development of knowledge of biological categories?

All the participants could identify all the exemplars that fit under categories at each level of the taxonomy. Even the youngest children understood and implemented appropriate natural kinds categorical sorts.

2. What is the course of development of induction?

Analyses of "yes" responses (inductions) revealed a significant effect of age, categorical distance, and their interaction, $F(6, 234) = 3.18$, $p <. 005$. More inductions occurred for exemplars of the same basic level – another bird (29%), with progressive decreases for following levels including same superordinate – another animal (10%), living things (7%), and inanimate objects (3%). Inductions decreased with age.

3. What is the course of development of deduction?

Both age and problem type jointly affected correct deductions, $F(4, 156) = 8.13$, $p <. 001$. MP responses were virtually perfect and MT performance was uniformly high (83-91%), but correct DA and AC answers increased from the youngest (48%) to the oldest group (73%). Thus deductive skill improved with age.

4. How are these cognitive skills related?

Individuals were credited with deductive skill if they solved every problem based on one premise and with inductive skill if for one clue, an inference was made to the closest exemplar and the strength of endorsement decreased with categorical distance. Deductive competency rose from 8% of the eight-year-olds, to 46% of the 11-year-olds, and 69% of the college students, but inductive skill dropped from 67% of eight-year-olds to 46% of 11-year-olds to 17% of college students. Induction and deduction were not correlated.

There were several important differences between this experiment and those that have been done in the past. Previous studies have not offered the subject the opportunity to say, "there is no way to tell" when asked for an answer. By requesting a "yes" or "no," the subject is forced into a response. It was interesting to note that the youngest children with the least amount of scientific sophistication were least likely to utilize the "no way to tell" responses while adults were most likely to use this response. Second, our warm-up inferential task utilizes solid and broken lines that may provide more abstract stimuli than natural kinds from which to make inferences. All age groups found it easier to make inferences using these abstract designs, than they did using biological kinds.

However, even on the warm-up task, the youngest children made more inferences than adults. A sub-population of the college students declined to say that any of the cards in the inductive warm-up task had a circle on the other side, although the instructions to each subject clearly stated that some of the cards in the examiners hand did, indeed, have a circle on the other side.

Finally, past experiments have used visual stimuli when asking participants to use reasoning to make inferences. It is possible that visual stimuli fostered inferences while this verbal task may have inhibited induction. These verbal stimuli required that participants utilize their own stored schema when deciding whether to infer anything about the relationship between the clue and the question. By not supplying any visual stimuli the participant has nothing except their own conceptual representations from which to develop categories. The lack of visual stimuli in the embedded task also potentially increased the level of difficulty and stifled induction. It is possible that participants performed better on the two warm-up tasks because they used visual stimuli, albeit abstract ones.

In an attempt to look at some of the initial questions about reasoning and natural kinds, the first study by Scholnick, et al. carefully examined the validity of the claim that young children's concepts are embedded in a causal theory. If these inductions are guided by a theory, then that same theory should also support the use of deductive strategies. The results of this earlier research project prompted additional questions to surface regarding variables that might constrain the use of reasoning in solving problems or generalizing to other categorical inferences.

The specific questions asked by the research in Study #2 follow from the results of Study #1, but they place the research in a different framework. Study #1 was situated within a neo-nativist approach to essentialism which assumes that there are no developmental differences in reasoning and no differentiation between the capacity to reason and the use of inductions or deductions. In Study #2, there are factors that might prompt reasoners of different ages to employ induction and deduction. By incorporating these factors the study was designed to determine what factors may have influenced the results of Study #1 and if the task presentation may have hindered inductive reasoning.

The first experiment produced results that were not totally expected. It became apparent from the data that the development and use of inductive and deductive reasoning did not appear to be related. In addition, while adults are thought to be skilled in inductions, very few were willing to use induction as a reasoning strategy for natural kinds.

To selectively examine factors that may have played a role in influencing the use of both inductive and deductive reasoning, Study #2 was changed in four specific ways including the presentation of the inductive and deductive tasks, the number of levels available to the participant, and the addition of two new variables: the language of reasoning and frame.

*Study Design and Task Modifications*

Three modifications were undertaken to deal with methodological issues. First, the task presentation was changed to separate the inductive and deductive reasoning tasks. In Study #1 these tasks were embedded. It was a concern that embedding the induction and deduction tasks may have confused participants and potentially inhibited their inductive reasoning performance. Because deduction focuses on deterministic reasoning and definite answers, it might inhibit the probabilistic generalizations that induction requires. Although it could be argued that the inductive tasks could have potentially influenced deduction, the college students did well on MP and MT tasks and performed as expected on the two tasks, AC and DA where probabilistic reasoning was relevant. Thus it was unlikely the induction task depressed deductive performance. To address this issue, in Study #2 tasks were presented in a serial format with induction always presented first and deduction second. Thus the inductive task was closer in format to the tasks used by Gelman to address induction for natural kinds.

Second, in Study #2 the targets of induction and deduction were expanded. The study used a format similar to Study #1 where the task presentation had included a target clue (blue jay, poodle). Participant choices had included questions about 4 generic (another bird, another animal, another living thing, something) and 4 more specific (parrot, horse, rose, chair) possibilities. Study #2 also included target clues (dalmatian, siamese), but instead of 4 generic and 4 specific choices, Study #2 included 6 specific choices for each target clue with varying degrees of biological resemblance from the target clue. These specific choices are listed in Table 4, shown later in this section. In the first study it could be argued that the jump from bird to animal or parrot to horse was substantial. Therefore, the second study inserted additional levels that would allow an analysis of more finely grained responses from participants. All target clues continued to contain a novel property. For dalmatians this property was magnesium and for siamese it was biotin.

A third format change was the use of drawn pictures of animal stimuli as opposed to strictly verbal clues used in the first study. This was done for two reasons. First, there was a concern that using only verbal cues drew too heavily on participant's mental representations and may have made the induction task too difficult. Pictures provided a more concrete reference for participants. Second, the use of pictures was also used to more closely reproduce the format of some of the earlier essentialism studies.

Additionally, the study was situated in a different theoretical context which focused on the factors that might influence the use of a potentially available reasoning strategy. Study #2 included two additional variables that were considered to have a potential impact on the reasoners responses: logical conjunctions and situational frame. The syntax used in Study #1 was expanded to include either *if* or *all* to determine if the phrasing of the primary clue might have influenced the type of reasoning used. The first experiment presented the clue as an *if* sentence. When reasoners were told, "*If* it is a poodle, it has biotin inside" induction might have been restricted if they interpreted this clue to mean, "*If and only if* this is a poodle, it has biotin inside." To examine this potential problem Study #2 was constructed to compare clues with different wording. Half of the participants heard clues phrased as *if* statements ("*If* they are siamese, they contain biotin."). The other half heard statements phrased as *all* statements ("*All* siamese contain biotin."). *All*, like *if* conveys the same conditional logic. The word *if,* which signals probability, might be more conducive to inductions whereas *all,* which implies a class inclusion relation, might be more conducive to deduction.

A second new variable that was included for Study #2 was the situational frame that participants were asked to use when they responded to the examiner's questions.

Analysis done on the first experiment revealed that the use of inductive reasoning was inversely related to the age of the participant. Young reasoners showed some use of induction whereas adults showed almost none. It was hypothesized that the frame in which the task was placed and the participants imagined themselves might affect the reasoner's willingness to take a chance on a potentially incorrect answer. Because induction requires arriving at an answer that is not an absolute truth based on available information, one possible explanation for this result is that older reasoners were less likely to risk what they perceived might be an incorrect answer. In the first study adults did not hesitate to answer deductive questions with "yes" or "no" answers, especially when they were sure that they were correct, but when answers became uncertain they were more hesitant.

It was interesting to note that very few of the youngest children responded with "no way to tell" when asked if a chair contained vitamin K. Although they had not been given any more information than the adults, they were willing to state that the chair did not contain vitamin K. In fact, many laughed at what they considered a silly question. At the same time, a majority of the adults responded "not enough information to tell" when asked this question further emphasizing their hesitation to respond in situations where they did not possess unequivocal facts.

Because the adults tested in the first experiment were all university students, it was also a concern that the educational experience of students, which encourages deductive reasoning and penalizes wrong answers, influenced their reaction to the task. Although students understood that participation in the experiment was the only criterion for receiving credit, it was a concern that they had not felt free to take a chance and possibly give a wrong answer under the experimental conditions of the first study.

While college students were not specifically tested in Study #2, it was possible that older children and in some cases even younger children might have similar concerns. By placing participants in specific frameworks that differed from their normal persona, we hoped to determine if frame influenced their reasoning strategy.

Two specific frame scenarios were developed. In the first scenario participants are asked to see themselves as scientists doing experiments thereby encouraging the use a scientific mode of thinking commonly associated with deductive reasoning. The second scenario placed the tasks in the frame of a risk taking investor who owns a pet store. By using the risky investor scenario, it was hoped that participants would be more willing to take a risk, and possibly utilize inductive reasoning. This does not assume that all risk taking behavior encourages inductive reasoning, or that inductive reasoning is necessarily associated with risky behavior. It does, however, present a scenario in which the boundaries of correct and incorrect answers may be considered less rigid.

These task modifications allowed for the analysis of both inductive and deductive data by age, frame (scientist/pet store owner) and logic syntax or reasoning language (if/all).

There was a final modification of study #1, the choice of sample. Because the folkbiology literature points to the possibility that culture and knowledge of nature (Coley, 2000) may have an impact on reasoning with natural kinds, a rural population was used to further determine if some of the results from Study #1 would persist with a different population. While the first study also included college students, Study #2 sought to examine whether groups that were closer in age (children and young adolescents) would show the same transition seen between children and adults found in the first study. In addition, because the children in Study #2 lived in a rural setting they potentially differed in experience from the typical college sample coming from diverse geographic regions and it would be inappropriate to compare the younger groups with the college students

Within each age cohort individual children were assigned to one of four groups: Scientist/If, Scientist/All, Pet Store Owner/If, Pet Store Owner/All.

The warm-up task from Study #1 was not included. The original purpose for task had been to determine if all participants could successfully do both induction and deduction. Because all participants were successful in Study #1, there was no need to repeat this task for Study #2.

*Participants*

Two age groups from a rural area outside of Albany, New York were selected for this study.

The two groups in Study #2 consisted of 40 7- to 9-year-olds ($M$ = 8 years 4 months, SD = 9 months) in grades 2, 3 and 4 and 40 11- to 13-year-olds ($M$ = 12 years, 6 months, SD = 11 months) primarily in grades 6, 7 and 8. The younger group was evenly matched between males and females; the older group contained 42 females and 38 males.

Students were allowed to participate in the study if they returned a consent form (Appendix 1) signed by a parent or legal guardian. Testing time was approximately 25 minutes per child.

All participants met individually with an examiner in a quiet room at their school. All children heard the Assent Form (Appendix 2), letting them know that they could end their participation at any time. One child chose to end participation early. These data were not included and a replacement child was recruited to maintain the sample of 80 children.

*Induction Task*

The induction portion of the task in Study #2 included a set of 24 stimuli. These stimuli were separated into two groups, each with its own target clue (dalmatian or siamese). Each of the target clue sets included 12 stimuli with decreasing levels of biological resemblance to the target clue. There were 6 different levels of resemblance with 2 instances at each level. These instances were pretested on a sample of young children to determine if, given the label, they could pick out the picture card which corresponded to it. The specific stimuli are listed in Table 4 on the following page.

Table 4

*Exemplars at Each Inductive Level for Each Target Clue*

| | Target | |
|---|---|---|
| Level | Dalmatian | Siamese |
| Specific Epithet | German Shepherd<br>Poodle | Short haired cat<br>Long haired cat |
| Family | Fox<br>Wolf | Lion<br>Tiger |
| Order | Skunk<br>Panda | Raccoon<br>Seal |
| Class | Cow<br>Giraffe | Pig<br>Elephant |
| Phylum | Eagle<br>Turtle | Parrot<br>Frog |
| Animal Kingdom | Crab<br>Grasshopper | Lobster<br>Spider |

Each child was also randomly assigned to one of four groups that determined the conjunction and frame and order of stimulus presentation. In each group, the first two conditions determined the frame that would be used. The second two conditions determined the logical conjunction assigned to each child. Children were also assigned to groups that determined the order of the target clues. The second two assignments included either Cat/Cat, Dog/Dog, Cat/Dog or Dog/Cat. If a child was in the Cat/Cat group, they would hear the inductive cat target clue and stimuli first, followed by the inductive dog clue and stimuli. They would also start the deductive portion of the task with the cat clue and follow it with the dog clue for the deductive task. All students participated in all portions of both the inductive and deductive tasks. Order of the stimulus presentations within each task (e.g., within the cat task) also was randomized.

Children began the induction task by hearing the introduction script and the script specified by their logical conjunction/frame group assignment beginning with the cat or dog clue designated by their clue order assignment. The following represents a sample induction script with a Scientist/If format. In this example the Scientist/If "cat" version is given. Other sample scripts are shown in Appendix 3.

**Introduction Script**

> We are interested in how kids think. So we have created a set of games that we would like to play with you that will help us understand how kids take science information that they have learned and apply it to other examples. We will be telling you something new and asking you to decide if that information is true in other situations too. Do you have any questions? Are you willing to participate in this experiment? If you decide at any point that you need to stop, please let me know and we can stop playing the game. Okay, let's play.

**Scientist/If Script**

> You are a careful scientist who works in a laboratory. You know that some animals have biotin inside them. Animals with biotin are very important to your research. Everyone is interested in animals with biotin! You have a friend who has told you some valuable information. He pulls out a picture and says "If they are siamese, they contain biotin." (show picture of siamese cat to child and place on table) You

need to find out what else has biotin so you can make important scientific discoveries and become famous. You don't have a lot of time or money and not everything has biotin, so what are you going to test?

After hearing the script, children were shown the series of animal picture stimuli to determine their willingness to use inductive reasoning in biological categorization. . They were shown pictures of animals noted in Table 4 and heard "Remember that if it is a siamese/dalmatian it has biotin (magnesium). *What about (fill in animal name). Would you say (a) I predict this has biotin (magnesium) (b) I predict this doesn't have biotin (magnesium) (c) I want to wait before I predict."* Both animal picture cards and response cards were shuffled before each participant and presented in random order.

*Deduction Task*

The second portion of the experiment tested the deductive skills of the individual. This portion was presented immediately following the inductive task. Participants continued with the same frame and logical conjunction that they heard in the induction section of the experiment. Because showing an actual picture would reveal the answer to a deductive syllogism, a task was developed that asked the deductive questions without visuals.

The examiner held a large book, similar to a picture book, and pretended to be reading from the book and examining it as though it contained pictures. To the participant it appeared that the examiner was looking at pictures and asking for help in making some appropriate decisions. The examiner was actually reading from a script and asking the participant about animals starting with the subordinate level (dalmatians or siamese). After the script for an individual level was read, the examiner asked the respondent to respond with 1) definitely yes, 2) definitely no or, 3) no way to tell. These options were also presented in random order across the entire deductive set so that approximately a third of the time the first option was definitely yes, a third of the time the first option was definitely no, etc.

The deductive task always began with the questions at the subordinate level and advanced to the basic level and then the superordinate level. The examiner asked the participant the four deductive syllogisms (MP, MT, DA, and AC) for each level in random order. Below is a sample script for the deductive task.

For continuity of this section, this script maintains the Scientist/If format.

**Subordinate Level Script: Siamese**

After you have been experimenting for a while you know that "If they are siamese, they contain biotin." You tell a friend, but she's puzzled and says, "Show me what you mean". She gets out a book of pictures and asks some questions. For each of her questions you can tell her definitely yes, definitely no or there is no way to tell. Can you help her?

- These are siamese, do they have biotin inside them?
- These are not siamese. Do they have biotin inside them?
- These have biotin inside them. Are they siamese?
- These do not have biotin inside them. Are they siamese?"

**Basic Level Script: Cats**

While you are answering the questions, you realize that "If they are cats, they have biotin inside them." You tell your friend and she pulls out a new set of pictures to really help her understand your information. She looks at the pictures and asks you questions. You need to tell her if the answer should be definitely yes, definitely no or wait to predict.

- These are cats. Do they have biotin inside them?
- These are not cats. Do they have biotin inside them?
- These have biotin inside them. Are they cats?
- These do not have biotin inside them. Are they cats?"

**Superordinate Level Script: Animals**

Finally, she says, I think I understand this information. "If they are animals, they have biotin inside them to help them grow." How will she act based on these statements? As she flips through the pictures she says "These are animals." Will she decide that they have biotin inside? Definitely yes, definitely no or wait to predict.

- These are animals. Do they have biotin inside them?
- These are not animals. Do they have biotin inside them?
- These have biotin inside them. Are they animals?
- These do not have biotin inside them. Are they animals?"

Once the child has completed both assessments the examiner asks the child if they have any questions and answers them as appropriate. Figure 3 graphically represents the flow of the experiment.

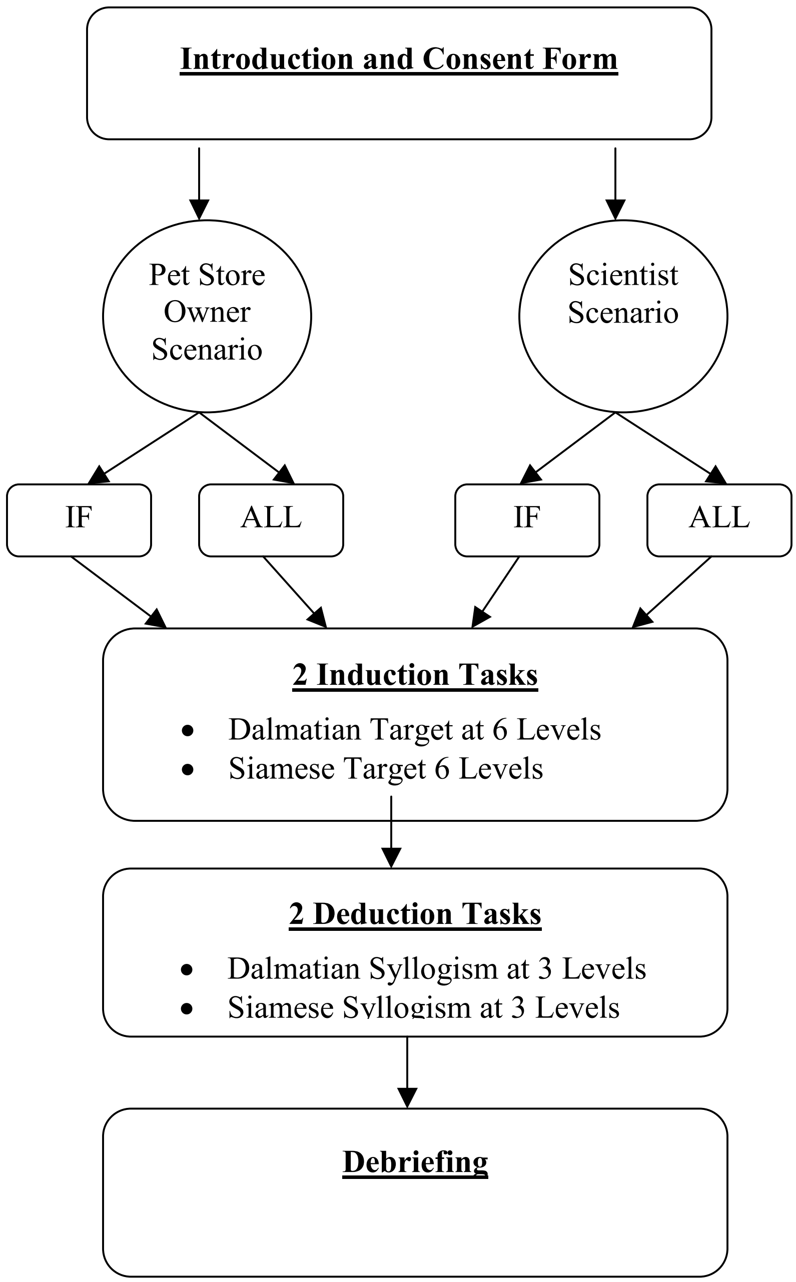


*Figure 3*. Graphic representation of experiment flow and group assignment.

## Chapter 3: Analyses

### *Research Questions*

Study #2 examines the following four research questions:

1) What is the influence of age on the use of induction and deduction in relation to natural kinds?

2) Are deduction and induction related skills?

3) What effect does the inclusion of more or less constraining logical conjunctions in the problem statement have on the use of induction and/or deduction in natural kinds?

4) What effect does the assumption of a more or less constraining situational frame play in the use of deduction and/or induction in natural kinds?

The first two questions address the same issues as Study #1 and allow comparison of the results across studies. The third and fourth questions examine the influence of logic syntax and frame on the development and use of inductive and deductive reasoning.

### *Return to the Questions in Study #1*

1) How do age differences affect the use of induction and deduction in relation to natural kinds?

Repeated measures ANOVAs were used to assess age differences with age, script (scientist/pet store owner), logical conjunction (if/all) and child gender as between participant variables. Inductive and deductive reasoning distance from the target clue and degree of difficulty were the repeated measures. Significant main effects were explored by follow-up independent samples *t*-tests. All repeated measures are reported using Huynh-Feldt corrected statistics.

*Induction – Age*

Unlike deduction, inductive distances from the target and problem difficulty are represented by the same variable. Because of this, only one inductive variable is necessary for analysis, and is characterized as the number "yes" responses to animals with an increasing distance of biological resemblance from the target item. The method of analysis was a 2(age) x 2(conjunction) x 2(frame) ANOVA with 1 repeated measure, the 6 different levels of cue distance. Similar to results found in Study #1, age was determined to be a significant factor in the use of induction, $F(1, 75) = 5.62$, $p=.02$ with an observed power of .65. There was also a significant interaction of age and inductive distance, $F(4.66, 349) = 3.41$, $p = .01$ with an observed power of .89.

Younger children made inductions at further distances from the target stimuli more frequently than older children. Using independent sample *t*-tests for further analysis (Table 5), this difference is significant at the fifth $t(78) = 3.69$ ($p<.001$) and sixth $t(78) = 2.26$ ($p<.01$) induction distances as illustrated in Figure 4 on the following page.

Table 5

*Mean Number of 'yes' Responses by Distance of Induction and Age (max. = 4)*

| Distance/Category | Mean | | Standard deviation | | t(78) = | |
|---|---|---|---|---|---|---|
| | Younger | Older | Younger | Older | *t* | p |
| 1. Specific Epithet | 2.95 | 3.25 | 1.24 | 1.06 | -1.16 | .25 |
| 2. Family | 3.03 | 2.98 | 1.12 | 1.31 | 0.18 | .86 |
| 3. Order | 2.13 | 1.73 | 1.40 | 1.18 | 1.38 | .17 |
| 4. Class | 1.85 | 1.68 | 1.29 | 1.16 | 0.64 | .53 |
| 5. Phylum | 1.98 | 1.00 | 1.25 | 1.11 | 3.69 | .001*** |
| 6. Animal Kingdom | 1.20 | 0.60 | 1.18 | 0.93 | 2.53 | .01** |

** .p<.01, ***p<.001

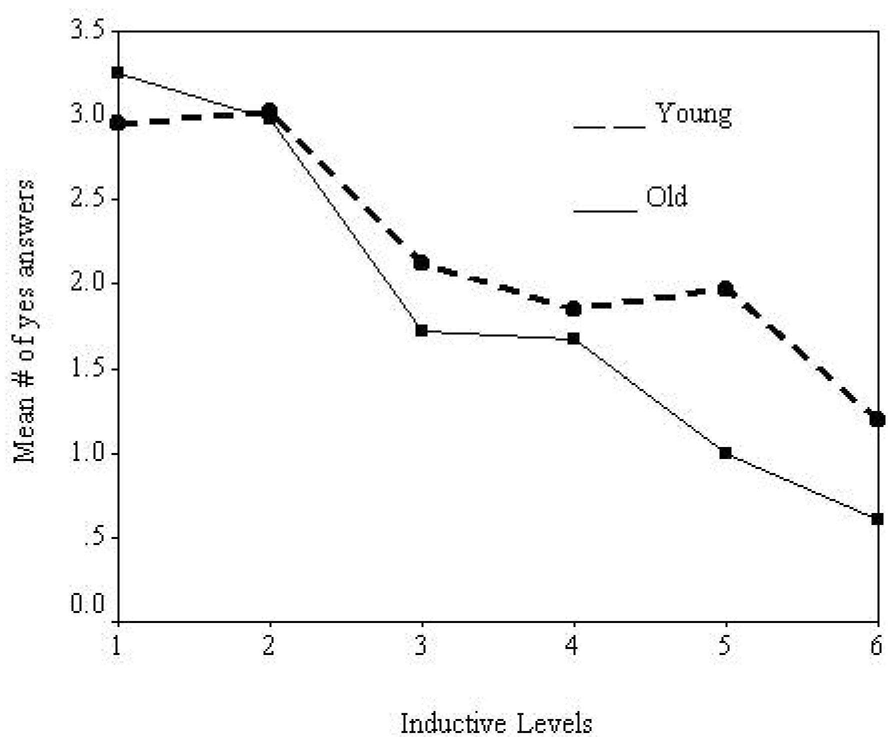


*Figure 4*. Relationship between age and level of induction reached

*Deduction – Age*

While the induction analysis combines distance and difficulty in the same variable, deduction must be analyzed differently. The four types of deductive problems represent different degrees of difficulty, although not with the evenly measured spacing of the inductive task. For example, MP restates the problem and MT inverts it, while DA and AC require the reasoner to consider all permissible instances that the initial premise allows. The content of individual problems also reflects the differing distances from the target clue: superordinate (animal), basic (cat/dog) and subordinate (siamese/dalmatian).

The first analysis of deductive reasoning accuracy examined problem difficulty and found results similar to those in Study #1. Using a repeated measures ANOVA with accuracy in each of the four types of deduction (MP, MT, DA, AC) as repeated measures, and age (7- to 9-year-olds and 11- to 13-year-olds), script (scientist/pet store owner), logic syntax (if /all), and child gender as between subjects variables, age is again shown to be a significant factor $F(1, 75) = 20.22$, $p = .001$ with an observed power of .99. Additionally, using the Huyhn-Feldt statistics, there was a significant interaction of deductive accuracy and age, $F(2.33, 23) = 10.25$ $p < .001$ with an observed power of .99. Using independent *t* tests, means for MP and MT were similar across age; however those for DA and AC show significant differences with older children superior on the two indeterminate inference problems (Table 6). Figure 5 shows a graphic representation of these data

Table 6

*Mean Number of Correct Deductions by Age and Problem Difficulty (max. = 6)*

| Problem Difficulty | Mean | | Standard deviation | | t (78) = | |
|---|---|---|---|---|---|---|
| | Younger | Older | Younger | Older | *T* | p |
| 1. Modus Ponens | 5.70 | 5.83 | 0.65 | 0.45 | -1.01 | .32 |
| 2. Modus Tollens | 4.97 | 5.03 | 1.14 | 1.25 | -0.19 | .85 |
| 3. Deny the Antecedent | 0.78 | 2.40 | 1.31 | 2.11 | -4.14 | .001*** |
| 4. Accept the Consequence | 0.45 | 1.85 | 0.99 | 2.06 | -3.88 | .001*** |

p<.001***

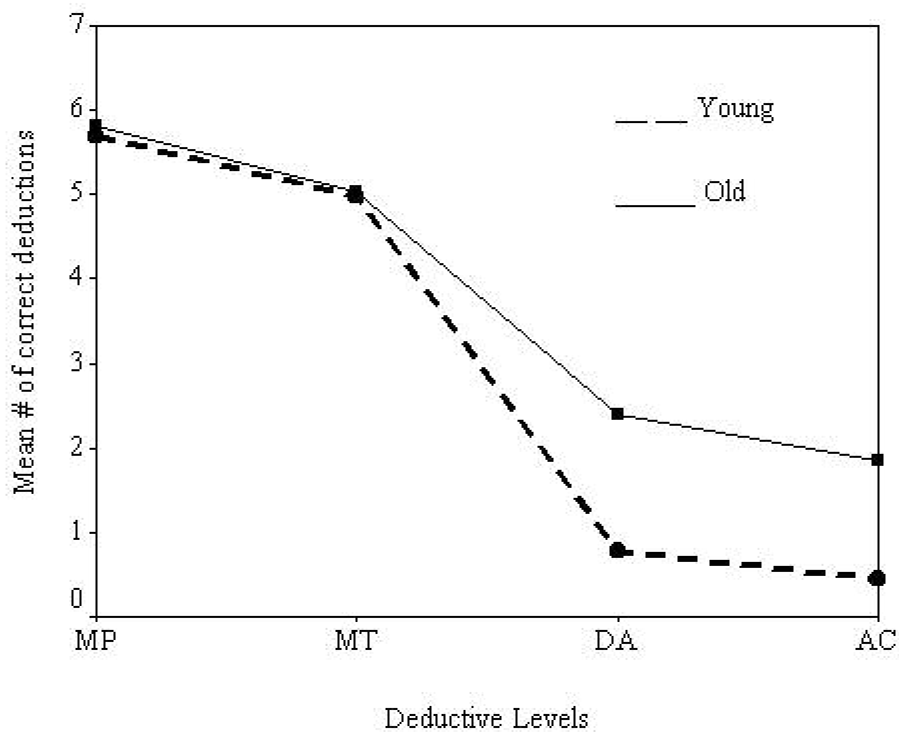


*Figure 5.* Mean number of correct deductions by age and type of deductive syllogism

The second variable, deductive distance, was also analyzed in a separate ANOVA. This variable, consisting of accurate deductions at three specific distances from the target clue (Subordinate, Basic, Superordinate), was used to examine the number of correct deductive responses with respect to distance from the target clue. Using a repeated measures ANOVA with 2 ages (7- to 9-year olds and 11- to 13-year olds), 2 scripts (scientist/pet store owner), 2 conjunctions (if/all) and (2) child genders as between subject variables and distance from the target clue as the repeated measures, age continues to be a significant variable $F(1, 75) = 18.43$, $p = .001$, but no interaction with level of abstraction was significant $F(1.83, 137) = .96$, $p = .38$.

*Deduction and Induction as Related Skills*

2) Are deduction and induction related skills?

It is notable that the two age groups differed in their pattern of performance with younger children making more inductive inferences and older children performing more accurate deductive inferences. These data suggest that the ability to accurately perform either inductive or deductive reasoning is directly related to age and that the two types of reasoning are not related with respect to natural kinds.

Because deductive reasoning is measured both by problem difficulty and distance from the target clue, it follows that a correlation matrix to examine the relationship between the distances of each type of reasoning is reasonable. To examine this, a correlation matrix including distance from the target clues for both induction and deduction was run with age partialled out. Table 7 shows the significant findings.

Adjusted for age, correlations of inductive and deductive distance showed sparse significance revealing only 3 significant correlations out of 15 correlations. Skill in making deductions at the deductive subordinate ($p = .02$) level was significantly related to a propensity to make inductive inferences to members of the same family (inductive level 2). However, people who were good at making deductions at the subordinate ($p = .05$) and basic ($p = .05$) deductive levels were less likely to make inductive inferences between animals who shared a class relation (inductive level 4). It should be noted that most of the correlations between deduction and induction across instances distant in the taxonomy were negative.

While significant, these relationships do not appear to represent a pattern that would suggest any correlation between the development of inductive and deductive reasoning in relation to natural kinds.

Table 7

*Intercorrelations between Distance Levels for Deductive and Inductive Task*

| Inductive Distance | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | | | Participants (n=77) | | | |
| 1) Ded. – Subordinate | .11 | .27* | -.07 | -.22* | -.20 | -.05 |
| 2) Ded. – Basic | .04 | .18 | -.07 | -.22* | -.13 | -.03 |
| 3) Ded. - Superordinate | .11 | .15 | .05 | -.18 | -.13 | -.05 |

p<.05*

## *New Analyses from Study #2*

### *New Variables from Study #2*

The second set of questions involves the additional variables that were incorporated into Study #2, reasoning language and frame. It was hypothesized that these variables would affect the use of induction, but not deduction in natural kinds.

3) What effect does the inclusion of more or less constraining logical conjunctions in the problem statement have on the use of induction and/or deduction in natural kinds?

### *Induction — Logical Conjunctions*

It was proposed that presenting the initial information in a sentence with either *if* or *all* would affect the way respondents perceived permission and would ultimately lead to a difference in their use of induction. Specifically, it was hypothesized that the presentation of factual information framed as an *all* sentence would facilitate the use of induction whereas the presentation of factual information framed as an *if* sentence would constrain the use of inductive reasoning.

An examination of the data, using a repeated measures ANOVA with 2 ages, 2 frames, 2 conjunctions and 2 child genders as between subjects variables, did not reveal any significant difference between the *if* and *all* groups $F(1, 75) = 0.05$, $p = .82$. Additionally, no interactions with conjunctions were seen $F(4.66, 349) = 0.37$, $p = .82$. Independent samples *t* tests shown in Table 8 showed similar results.

Table 8

*Mean Number of 'yes' Responses by Distance of Induction and Reasoning Language (max. = 4)*

| Distance/Category | Mean | | Standard deviation | | *t* (78) = | |
|---|---|---|---|---|---|---|
| | If | All | If | All | *t* | p |
| 1. Specific Epithet | 3.05 | 3.15 | 1.22 | 1.99 | -.39 | .70 |
| 2. Family | 2.90 | 3.10 | 1.41 | 0.98 | -.74 | .46 |
| 3. Order | 2.03 | 1.83 | 1.25 | 1.36 | .69 | .50 |
| 4. Class | 1.78 | 1.75 | 1.21 | 1.26 | .09 | .93 |
| 5. Phylum | 1.58 | 1.40 | 1.22 | 1.34 | .61 | .54 |
| 6. Animal Kingdom | 0.93 | 0.88 | 1.14 | 1.07 | .20 | .84 |

*Deduction —Logical Conjunctions*

It was also predicted that that the use of the words *if* or *all* in the initial premise would not cause any difference in the use of deduction when reasoning about natural kinds. Because deduction is reasoning with a specific answer, the phrasing of the stimulus should not influence the responses. Two repeated measures 2 x 2 x 2 x 2 ANOVAs, using the same between subjects variables, were used to analyze deductive difficulty and distance, similar to analyses used to examine the influence of age.

As predicted, there was no significant effect on the level of performance related to problem difficulty (MP, MT, AC, DA) achieved by reasoners in relation to deduction *F(*1, 75) = 1.73, p = .19 nor was there any interaction *F(*2.33, 335.50) = 1.24, p = .29. Further analysis by *t*-tests showed similar results (Table 9).

Table 9

*Mean Number of Correct Deductions by Reasoning Language and Problem Difficulty (max. = 6)*

| Problem Difficulty | Mean | | Standard deviation | | *t* (78) = | |
|---|---|---|---|---|---|---|
| | If | All | If | All | *t* | p |
| 1. Modus Ponens | 5.73 | 5.80 | 0.60 | .52 | -.60 | .55 |
| 2. Modus Tollens | 5.00 | 5.00 | 1.18 | 1.22 | .00 | .15 |
| 3. Deny the Antecedent | 1.27 | 1.90 | 1.75 | 2.06 | -1.46 | .61 |
| 4. Accept the Consequence | 1.05 | 1.25 | 1.52 | 1.97 | -.51 | 1.00 |

Deductive problem distance was also examined. The effect of reasoning language was not significant, *F(*1, 75) = 1.53, p = .22, nor was there an interaction with any variable *F(*1.83, 137) = .29, p = .73. Table 10 shows additional *t* tests confirming these findings.

Table 10

*Mean Number of Correct Deductions by Reasoning Language and Distance (max. = 8)*

| Deductive Problem Distance | Mean | | Standard deviation | | t (78) = | |
|---|---|---|---|---|---|---|
| | If | All | If | All | *t* | p |
| 1. Level 1 - Subordinate | 4.58 | 5.00 | 1.412 | 1.75 | -1.19 | .24 |
| 2. Level 2 – Basic | 4.40 | 4.60 | 1.150 | 1.46 | -0.68 | .50 |
| 3. Level 3 - Superordinate | 4.03 | 4.28 | 1.423 | 1.63 | -0.73 | .47 |

4) What effect does the assumption of a more or less constraining frame play in the use of deduction and/or induction in natural kinds?

*Induction — Frame*

It was predicted that participants who perceive frame scenarios with few rigid boundaries (pet store owner) might be more likely to use induction as a reasoning strategy in a task involving natural kinds than those who perceive a more rule bound frame (scientist). Because induction is reasoning from the specific to the general, it always holds the potential for inaccuracy and can be perceived as an intellectually riskier option. The data to address the question were extracted from the same ANOVAs described in the previous paragraphs.

While there was no main effect of frame $F(1, 75) = 1.17$, $p = .48$, the data did reveal an interaction that approached significance using the Huynh-Feldt statistics $F(4.66, 349) = 2.23$, $p = .06$ with an observed power of .70. The results of *t* tests

(Table 11) show significance only at the specific epithet level. Figure 6, on the following page, shows this relationship.

Table 11

*Mean Number of 'yes' Responses by Distance of Induction and Frame (max. = 4)*

| Distance/Category | Mean | | Standard Deviation | | *t* (78) = | |
|---|---|---|---|---|---|---|
| | Scientist | Pet Store | Scientist | Pet Store | *t* | p |
| 1. Specific Epithet | 2.80 | 3.40 | 1.29 | 0.93 | -2.39 | .02 |
| 2. Family | 3.20 | 2.80 | 0.99 | 1.38 | 1.49 | .14 |
| 3. Order | 1.83 | 2.03 | 1.32 | 1.29 | -0.69 | .50 |
| 4. Class | 1.90 | 1.63 | 1.28 | 1.17 | 1.00 | .32 |
| 5. Phylum | 1.40 | 1.58 | 1.26 | 1.30 | -0.61 | .54 |
| 6. Animal Kingdom | 0.78 | 1.02 | 1.03 | 1.17 | -1.02 | .31 |

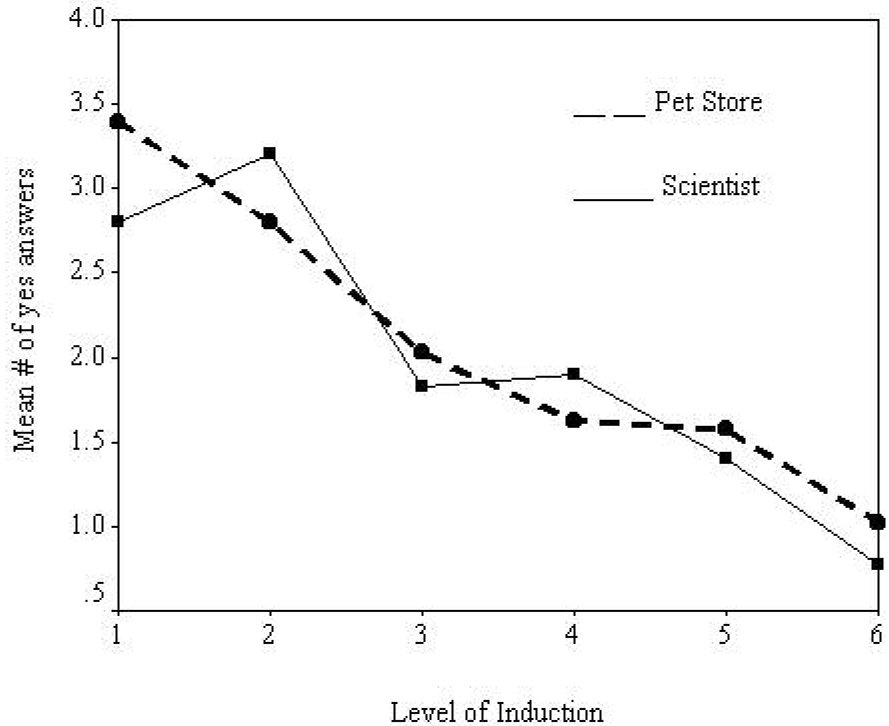


*Figure 6.* Mean number of correct answers for inductive levels by frame

*Deduction - Frame*

It was also predicted that the use of different frames would have no effect on either the use of deduction in relation to difficulty or distance in natural kinds. Because deduction can only produce an absolute answer, risk should not affect the outcome. This proved to be true, and no significant differences were found between either the scientist or pet store owner scenarios whether the ANOVA analyzed the impact of problem difficulty or distance from the target. In each case, data were analyzed using a repeated measures ANOVA with 2 ages, 2 frames, 2 types of reasoning language and 2 child genders as between subjects variables. Results are as follows; for distance, $F(1, 75) = 0.003$, $p = .96$, $F(1.83, 137) = .85$ and for difficulty, $F(1, 75) = .001$, $p = .97$, $F(2.24, 174) = .10$, $p = .93$. Tables 12 and 13 showing *t*-test results did not show any significance.

Table 12

*Mean Number of Individual Correct Deductive Answers by Frame and Distance (max. = 8)*

| Deductive Problem Distance | Mean | | Standard Deviation | | t (78) = | |
|---|---|---|---|---|---|---|
| | Scientist | Pet Store | Scientist | Pet Store | *t* | p |
| 1. Level 1 - Subordinate | 4.85 | 4.72 | 1.44 | 1.75 | .35 | .73 |
| 2. Level 2 – Basic | 4.55 | 4.45 | 1.26 | 1.38 | .34 | .74 |
| 3. Level 3 - Superordinate | 4.03 | 4.28 | 1.66 | 1.40 | -.73 | .47 |

Table 13

*Mean Number of Individual Correct Deductive Answers by Frame and Problem Difficulty (max. = 6)*

| Problem Difficulty | Mean | | Standard Deviation | | *t* (78) = | |
|---|---|---|---|---|---|---|
| | Scientist | Pet Store | Scientist | Pet Store | *t* | p |
| 1. Modus Ponens | 5.75 | 5.78 | 0.54 | 0.58 | -.20 | .84 |
| 2. Modus Tollens | 4.95 | 5.05 | 1.24 | 1.15 | .06 | .95 |
| 3. Deny the Antecedent | 1.60 | 1.58 | 1.84 | 2.04 | .13 | .90 |
| 4. Accept the Consequent | 1.18 | 1.13 | 1.74 | 1.79 | -.37 | .71 |

Neither scenario played any discernable role in the use of induction or deduction, with age being the only consistent marker over all groups.

# Chapter 4: Discussion

As noted before, it is claimed that natural kinds are organized into an intuitive hierarchical taxonomy that encourages inductive reasoning. Although there are occasional novel exceptions that do not appear to fit neatly into the taxonomy such as whales, that are mammals but look like fish or bats that are also mammals but look like birds, most instances share both observable and unobservable characteristics that allow them to be easily placed into categories. These factors encourage the use of induction in natural kinds.

## *Influence of Age on Induction*

Although neo-nativists claim that young children use an intuitive theory of natural kinds as the basis for making inductions, numerous researchers (Carey, 1985; Gelman, 1988, 2003, 2004; Lopez, Gelman, Guthiel, & Smith, 1992; Medin, 1989; Medin & Atran, 1999; Osherson, Smith, Wilkie, Lopez, & Shafir, 1990) have shown that multiple variables such as age, culture and reasoning strategy may influence inductive reasoning. In this discussion, the results of Study # 2 are reported within that framework. These results include developmental changes related to age on inductive and deductive reasoning; the relationship between these two types of reasoning; the impact of presenting that information as an *if* or *all* statement; and the influence that frame (pet store owner, scientist) might have on reasoning strategies. The following discussion draws from research cited in the first chapter to assist in understanding what role each of these variables might play in the development of inductive and deductive reasoning.

In both Study #1 and Study #2, age was a significant factor, with younger individuals being more likely to make inductions at greater distances from the target clue than older participants. But, older children were more likely to make correct deductions. These findings indicate that age may be a factor in children's use of inductive and deductive reasoning. In the Study #1, younger participants (8- to 11-year-olds) made more inductions at farther distances from the target clue than college students. While the age comparison proved to be significant, the age difference between these groups provided too substantial a gap to pinpoint a specific transition period when children might shift from using more induction to using less induction in relation to natural kinds. In Study #2, the age distance between the two groups being compared (7- to 9-year-olds and 11- to13-year-olds) was reduced, providing an opportunity to more clearly determine when children might make a transition to different inductive reasoning strategies. However, age continued to be a significant factor, with younger participants in Study #2 being more willing than older participants to extend inductions to animals with less biological resemblance and older participants behaving similarly to the college students in Study #1. Because this age variable is significant, it is important to consider why age might be a factor and what processes might be involved that would account for this difference.

One possibility is that the conceptual basis of the biological taxonomy changed.

## *Reported Age Shifts*

### *Essentialism*

Gelman (2003, 2004) claims that young children use a representational, causal, placeholder form of essentialism to draw conclusions about natural kinds. In this version of essentialism children tap their understanding of an unobservable essence within the animal that allows it to have the characteristics that give it category membership. For example, what makes a lion “lion-like?” A causal essence may be the “substance, power, quality, process, relationship, or entity that causes category-typical properties to emerge and be sustained” (Gelman, 2004). Children’s lack of complete scientific understanding of this essence is labeled as a place holder notion. It has been shown (Asuti, Solomon, & Carey, 2004; Keil, 1989) that children are aware that this essence remains constant across time and within generations. If we are to assume that essentialism is utilized by children to make inductions about natural kinds (see Sloutsky & Fisher, 2004; Strevens, 2000 for alternate arguments), then one thing that remains unclear is whether this theory is used continuously throughout development and potentially into adulthood, even in a modified form, as suggested by Gelman (2003) or if it is altered, or is possibly inhibited by concurrent developmental changes and at what point this potential modification in thinking occurs.

Since the 1980s, Gelman and others have presented numerous experiments exploring essentialism as a possible explanation regarding children’s use of inductive reasoning in natural kinds. One crucial variable in this research has been the age of the participants. The majority of studies have been done with children who are no older than third grade and primarily under the age of seven. There is a good reason for this. To be able to claim that children are using an essentialist theory, researchers have sought to show that scientific knowledge is not a confounding influence on children's inductive thinking. The only way to do this is to test children who have the bare minimum of scientific sophistication. It stands to reason that the younger the child, the less likely that their reasoning would reflect any impact of biological knowledge.

*Taxonomy*

Some studies have reported that children's understanding and applications of strategies for inductive reasoning do appear to shift with age. When determining children's understanding of basic and subordinate class inclusion, Johnson and Mervis (1997) concluded that although task as well as age can impact responses, by age 7 children's responses were similar to those of adults. It was also at this age that knowledge of biological taxonomies appeared to influence children's choices. Gottfried, Gelman, and Schultz (1999) speculated that children progressed from an essentialist form of beliefs to a more biocentric approach to biological concepts by the age of eight. Even in Gelman's original work (1988), it was noted that by second grade inductive inferences were influenced by more elaborate domains of scientific knowledge. According to Gelman, this did not imply that children failed to draw upon a theoretical notion of essentialism to guide their thinking. Instead she argued that this new level of knowledge simply meant a change in the "sophistication and complexity of their inferences." Others disagree and claim there are shifts. For example other researchers, (Sloutsky, 2003; Sloutsky & Fisher, 2004a, 2004b;

Sloutsky & Spino, 2004) who adamantly argue that children do not use essentialism and instead depend on subtle perceptual clues when reasoning about natural kinds, claim that by age 7 or 8, children appear to be shifting even their perceptual strategy and starting to look more like adult reasoners.

Studies in argument strength also show differences based on age and experience. This may reflect fewer levels in the hierarchy for some children or the fact that the individual does not take the whole taxonomy into account when doing induction.

Descriptions of argument strength in Chapter 1 showed that the utilization of argument strength is not the same across age levels, reflecting difference in the ability to use taxonomic knowledge to reach conclusions. While Osherson et al., (1990) showed adults using diversity, similarity, typicality and sample size, studies with children by Lopez et al., (1992) were not able to replicate these results. It appeared that kindergartners did not use either diversity or sample size as an inductive heuristic. Second graders were able to use diversity and sample size, but only if the examiner supplied the superordinate category which encompassed the diverse instances.

It would appear that in order to use diversity a certain level of knowledge is necessary. The reasoner must be able to understand and develop superordinate categories. This knowledge grows and changes with time and experience. Thus previous researchers have suggested that there may be an age shift in the use of inductive strategies.

*Cultural Influences*

If we assume, as others have, the increasing age also portends an increase in knowledge we must also acknowledge that some groups, for example the Itzaj Mayans, gain a breadth and depth of knowledge at a different rate than the U.S. population. As noted in Chapter 1, direct experience with natural kinds may produce a different level and type of knowledge than what is normally found in an academic environment. And in the Menominee culture, even young children have been shown use reasoning strategies based on their different and more complete understanding of the biology in their environment. This directly influences their use of inductive reasoning (Ross et al., 2003).

Research in the folkbiology tradition has also shown that the influence of knowledge is not simply one of expertise. The use of that expertise may also influence induction by showing that individuals may construe biological categories differently. Atran's studies (1999) in folkbiology with the Itzaj Indians show a different side of induction within a society where adults may not possess specific scientific knowledge as Western culture defines it, but do have an intimate acquaintance with different plants and animals. The Itzaj categorize natural kinds into species-like groups in a taxonomic hierarchy, but the taxonomy differs from the Linnean taxonomy. Additionally, the Itzaj people also use an induction strategy that references their own environmental needs, dependence, and interaction with the natural kinds environment. For example, when asked about certain arboreal animals (spider monkeys, howler monkeys, coatimundi and kinkajou) which do not belong to the same scientifically classified family, the Itzaj classified them as being part of the same category because they are tree dwellers (Coley et al., 1999). By doing this they organized animals in a way that reflected their environment and interaction with these animals, not necessarily a scientific taxonomy. Their responses were similar to participants in Malt's 1994 study where respondents categorized water based on its function and location rather than its actual chemical makeup. Thus if inductive skill is based on the scope of generalizations, the scope is different for different cultures.

*Does Knowledge Facilitate or Inhibit Inductions?*

If, as Gelman claims, knowledge should allow children to draw upon a more complex theoretical base grounded in increased knowledge, then all of the preceding would argue that older children would make more inductions across a wider scope of instances. But the results of Study #2 show just the opposite. Perhaps it is possible that in some cases increased knowledge actually inhibits inductive reasoning. Or maybe the shift is more subtle than we have been able to measure. Possibly the shift takes place as a variety of factors converge including natural kinds knowledge, skill in applying different strategies for reasoning and experience in the natural world.

From a developmental standpoint it is important to understand how children develop theories or strategies that they use to apply inductive reasoning in natural kinds. And all researchers have suggested that knowledge plays a role in this use. What has not been answered is whether this role changes over time and if it does, when does it change and why does it change then? Study #2 would seem to suggest that children do start to use a different strategy at they approach early adolescence. It could be argued that their knowledge base has increased at this point and are therefore they are more constrained in their reasoning. Essentially, they know more and at the same time they know more about what they don't know. It may also be that younger children's lack of complex knowledge within specific categories allows them to use induction at further levels of biological resemblance. In the expertise literature (Chi & Koeski, 1983; Gobbo & Chi, 1986) the hierarchy of experts is more differentiated with a greater number of levels, i.e., there is greater inductive distance between a dog and a wolf for the individual specializing in canine mammals and the differences between related categories are more prominent making generalizations harder. To test this would require looking at what children know that is the basis for induction, i.e., their causal theories and perceptual analyses.

More importantly, this study used stimuli with even greater divergence from the target clue than previous research and found an age difference between pre-adolescents and younger children for categories that were further from the core example. These are the instances not usually employed by Gelman. While the data from Study #2 do not reveal exactly what strategy children are using, what it does suggest is that whatever strategy is being employed shifts as they age and one index of this is the extent to which they will make inductive generalizations.

*Influence of Age on Deduction*

For deductive reasoning the age trend was reversed with older children scoring significantly higher on the two more difficult forms of deductive reasoning (AC and DA) compared to younger children, although neither group showed a difference when measured on deductive distance from the target clue. In other words, children performed as would be expected on the deduction task. Framing the task in terms of basic, subordinate or superordinate categories did not make a difference in successful completion of the task. One limitation of this task was that the superordinate tasks came later than basic level tasks, but the logic of inference should have been the same.

Young children are able to distinguish between inductive and deductive tasks (Galotti, Komatsu, & Voelz, 1997) and report feeling more certain of their answers in deduction when presented with syllogisms. As stated before, deductive skill and confidence in that skill increases as children age. Study #2 confirms this finding; however age does not guarantee complete deductive success as reflected in the first study's statistics of a 67% success rate for college students. This, too, is a common finding in the literature (Johnson-Laird, 1995).

The more interesting result is the continued dichotomy between age and success with different types of reasoning. Although the groups in the second study were even closer in age than those in the first study, there was still a statistical difference in age for successful deductive reasoning. As the correlation analysis showed, while there was very modest correlation on a few levels, overall it appears that induction and deduction are not correlated, confirming the results of the first study.

It should, however, be noted that while there was an age effect it was not a sharp dividing line between the different age cohorts and that the age difference that was seen took place in the two categories farthest from the target clue.

### *Role of Reasoning Language in Induction and Deduction*

The first experiment pointed to a clear differentiation between deduction and induction. On closer inspection, it was thought that the way in which the stimuli were presented might have influenced, and possibly constricted, the reasoner. By using the word *all* to encourage greater inclusion and contrasting it with the word *if* to show greater reasoning constriction, it might be possible to show that reasoning language was influencing the reasoning outcomes. While language can have a powerful influence on the way in which people perceive categories (Gelman, & Heyman, 1999) this was not shown to be the case with *if* and *all*, two conjunctions which are used to link categories with a property. Neither age group was influenced by the change in conjunction, leading to the speculation that other factors were influencing the difference in successful reasoning.

It was also predicted that because deduction should not be influenced by logic syntax, that deduction performance would not be different between the *if* and *all* groups. This proved to be the case for both deductive distance and deductive difficulty.

*Role of Frame in Induction and Deduction*

A third variable examined was that of a change in the framing of both reasoning problems. Study #2 contained 2 frames, Pet Store Owner and Scientist. The hypothesis was that frame would affect the reasoning of natural kinds. This strategy was based on results from the first experiment and informal discussions with college student participants in the first experiment who made few inductions although they were clearly at an educational level that would allow them to make reasonably educated guesses. On more than one occasion they made no inductions at all, even on closely related items. Discussions revealed that they attributed this to their current learning strategies (e.g., there is a potential for retribution for guessing anything that I don't know as fact). The youngest children (5 to 7-year-olds) did not express this concern, but it was possible that children between the ages of 7 and 9 were beginning to perceive the penalties of guessing as they advanced in school.

These informal observations suggested that it was possible that external influences besides knowledge or theory could be influencing the use of induction, especially if college students perceived, correctly or not, that incorrect answers carried consequences that they sought to avoid.

Because all of us use induction in our daily lives and some have argued that induction can be implemented differently under different circumstances (Malt, 1994; Sloman, 1993), the college setting could be construed as artificially constraining. If that was the case, there might be other factors that were also artificially constraining induction. In order to address that issue, it was hoped that the two different frames would provide results that showed that induction could be influenced if people perceived that they had a different environment (more restrictive, less restrictive) in which to make decisions.

The results of the analysis of frame are mixed. Story frame did have a significant impact with pet store owners (i.e., the riskier group) eliciting more induction than the scientists. This result would seem to point to the possibility that frame; even one suggested by an experimental design and not directly related to an individual's day to day life, can have some influence on the willingness to use induction in natural kinds. However the influence of frame did not go beyond the first level of induction. At that level the pet store owners (riskier group) were the most willing to make inductions. However, the data suggest that induction can be influenced by artificial frame changes. If that is true, then it would seem that a theory alone could not be the basis for inductions, nor knowledge alone. Other factors might also enhance or deter the reasoner's use of induction. The only obvious differences seen for these groups were at the specific epithet level, but the important point is that while modest, this finding does suggest that artificial frames can be a factor in reasoning.

While the scenarios presented for this experiment were developed to enhance a change of framework to elicit either more or less risky choices, it is possible that younger and older children did not imbue them with the same degree of risk. Future experiments could be enhanced by including a separate measure of risk taking that determined the individual's initial proclivity for risk taking to determine how the scenario either enhanced or thwarted normal tendencies.

While much has been done to examine the influence of previous knowledge, age, and visual perception, a measure of environmental influences has been sparse. It would enhance the research to incorporate these measures as part of the total picture when understanding this portion of the 'why' question when examining the results of natural kinds categorization research.

*Summary*

The nature of underlying reasoning for the use of induction and deduction in relation to natural kinds is of great interest and controversy. It is possible that an unchanging abstract essentialist theory is not the basis for the use of induction. This study has shown that age and context may both play a role in the development and use of induction. That suggests that children are not basing their inductions in natural kinds solely on an underlying unchanging theory, but instead are using a dynamically changing theory and accumulating information in concert with frame influences to arrive at reasoning decisions. If essentialism were the basis of children's understanding of natural kinds, their use of induction should be constant. Instead their use of induction decreases.

The findings in this study do not support an essentialist or neo-nativist theory of conceptual development. Essentialism does not explain why children go from using induction to limiting their induction. Either the child's theory and knowledge or their uses of theoretical assumptions and factual information have changed. Studies of essentialism have used progressively younger children, while ignoring older children. It is with these older children that we see essentialism fall apart. If children know that natural kinds have essences that define them, why would they ignore this as they get older? Perhaps their knowledge stresses the differences among organisms. Perhaps they have learned to be more cautious about making inductive leaps. They prefer solid evidence. Consequently children may be using the content knowledge that they gain to restrict their induction while they simultaneously use their increased understanding of logic to increase their deductive skills. This finding would support Piaget's claim that abstract deductive reasoning emerges slowly and is found only in older children and adults. Piaget (Inhelder & Piaget, 1958, 1964) would also doubt that young children would base their reasoning on abstract theoretical concepts.

Instead, these results may lend credence to proponents of the IP model. Children appear to change and refine their reasoning strategies as they age. They get better at deduction and they are more cautious about induction. It is possible that as they gain experience with reasoning and expand their content repertoire, they become clearer about the kinds of conclusions one can draw from evidence. Alternatively their knowledge is organized differently. Older children and experts have a more refined hierarchy with greater differentiation of levels. The refinement may also block inductions. We know differences in induction exist but the data do not pinpoint the source of the differences, in knowledge, strategy or willingness to make inductions. The intriguing question of exactly why and when children go from a more expansive use of induction in natural kinds to a more restrictive use as they age still remains.

More importantly, if the assumption that broader use of induction in combination with strong deductive skills is the basis of discovery, how do we use this knowledge to encourage older learners to maintain their use of inductive strategies while giving them the tools to use it in a thoughtful and accurate manner rather than a restrictive way that inhibits their ability to make the inductive jumps? What specific barriers are keeping them from using inductive reasoning and how do we thwart those barriers?

There are, of course, limitations to this study. While scenarios used in the induction task between pet store owner and scientist were carefully matched and designed to elicit risk and non-risk frame environments for children, I believe that there is the potential for developing more effective scenarios that might elicit even stronger results. In addition, future research could also develop inductive and deductive tasks that are more closely matched. Study #1 embedded induction and deduction tasks so that the focal instances closely resembled one another. But it was possible the child became confused about the kind of reasoning to use. In Study #2 the tasks were separated but the deductive tasks spanned fewer levels. Despite the methodological differences, the data in Study #2 replicated the initial study. Nevertheless it would have been better to have made the induction and deduction tasks more similar and to have balanced the order of presentation. Additionally, in future experiments I would discuss with each child why they made the choices they did. These responses could be coded and examined to see if children are able to identify their own thinking strategies and if those responses predict the level of induction or deduction shown in the analysis.

The results of this study are preliminary, and more research is necessary to determine if use of induction is a combination of many of the puzzle pieces suggested by other researchers in addition to this study. It seems plausible that both nature and nurture play a role and possibly play that role differently depending on the age of the individual. This is a complex problem that requires a careful look and continuing research to determine the answers.

As Houde (2000) pointed out, the mind is a "jungle where a variety of competencies in the infant, child and adult are likely at any moment to collide, to clash, to compete (at the same time as they are being constructed)." That internal change in combination with environmental input might possibly be what is driving the development of inductive and deductive reasoning in relation to children and natural kinds.

# Appendices

Appendix 1

# PARENTAL PERMISSION FORM

**How Children Think about Animals**

*I wish to allow my child to participate in an experiment of reasoning being conducted under the supervision of Ellin Scholnick, Ph.D. in the Department of Psychology at the University of Maryland, College Park.*

*The purpose of this research is to study how reasoning skills develop in children. It explores how people apply information that they know to new situations.*

*The procedure involves one session approximately 25 minutes in length. During that time my child will participate in 2 critical thinking tasks. In each task my child will be told information about one animal and their job is to figure out whether the same information applies to other animals. For example, if they know something about one bear, would it tell them something about another bear or a bee? During both tasks a trained examiner will give your child information about specific animals and then ask your child how this information applies to other specific animals. The experiment will be done during class time and will not have any effect on your child's grade.*

*All information collected in this study is confidential to the extent permitted by law. I understand that the information provided will be grouped with other information and that my child's name will not be used.*

*Participation in the project involves minimal risks.*

*The experiment is not designed to help me or my child personally, but to help the investigator learn more about children's reasoning. My child is free to ask questions or withdraw from participation at any time and without penalty. My child may decline to answer any of the questions and will not be penalized in any way.*

*Investigator Contact Information:*

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*Investigational Review Board Contact Information:*
*If you have questions about your child's rights as a research subject or wish to report a research-related injury, please contact:*
***Institutional Review Board Office***
***University of Maryland***
***College Park, Maryland 20742***
***(e-mail) irb@deans.umd.edu; (telephone) 301-405-4212***

NAME OF PARENT ______________________________

SIGNATURE OF PARENT ______________________________

DATE ____________

Appendix 2

ASSENT FORM

How Children Think about Animals

Thank you for participating in our study. We are going to do two tasks that have to do with animals. In each case I am going to tell you information about one animal and your job is to figure out whether the same information applies to other animals. For example, if you knew something about one bear would it tell you something about another bear or a bee? People differ in what they think so don't worry about your answers and you can stop at any time.

If you decide that you don't want to answer any of the questions, just let me know. There isn't any penalty for not answering any question. Also, being part of this experiment doesn't help or hurt your grades in any way.

The first task takes about 10 minutes and the second task takes about 15 minutes.

You are free to ask any questions at any time and you may stop participating if you would like. Only other researchers that are working on this study will be shown your answers.

As researchers we are very interested in learning about how children think, but we can't find out answers to some of our questions about 'thinking' unless kids like you are willing to help us do this important work. You can be very proud of the fact that today, you helped us get a little closer to understanding how kids think. Today, you helped science !

This form was read to all participating students

________________________________________
Examiner Signature/Date

Appendix 3a

Sample Script - Induction

Task Script

<u>Scientist/ALL – DOG</u>

**EXAMINER:**

You are a careful scientist who works in a laboratory. You know that some animals have magnesium inside them. Animals with magnesium are in very important to your research. Everyone is interested in animals with magnesium!. You have a friend who has told you some valuable information. He pulls out a picture and says, **<u>"All Dalmatians contain magnesium</u>" (show participant picture of Dalmatian).** You need to find out what else has magnesium so you can make important scientific discoveries and become famous. You don't have a lot of time or money and not everything has magnesium, so what are you going to test?

Remember, all Dalmatians contain magnesium. (repeat for first 5 animals only)

What about (fill in animal name). Would you say a) I predict this has magnesium b) I predict this doesn't have magnesium c) I want to wait before I predict.

By now you trust your friend's advice and you are happy when he gives you more information. He pulls out a new picture **(Place picture of Siamese on table)** and says **<u>"All Siamese contain biotin"</u>**. You test some Siamese and are scientifically successful. You want to test some more animals based on this information so you can become a famous scientist. You are offered some things to test.

Remember, all Siamese contain biotin.

What about (fill in animal's name). Would say a) I predict this has magnesium b) I predict this doesn't have magnesium c) I want to wait before I predict.

- Proceed to Deduction Task – Scientist/DOG

Appendix 3b
Sample Script - Deduction

Store Owner/ALL – DOG

Subordinate Level: Dalmatian

Script:
Okay, now let's pretend I'm your friend and after you have been buying and selling for a while you know that "All Dalmatians contain magnesium." You tell me that, but I'm a little puzzled so I say, 'Show me what you mean. I have a book of pictures and I'm going to ask you some questions. For each of my questions you can tell me definitely yes, definitely no or there is no way to tell. Can you help me?"

Script:
There are Dalmatians. Do they have magnesium inside them?
These are not Dalmatians. Do they have magnesium inside them?
These have magnesium inside them. Are they Dalmatians?
These do not have magnesium inside them. Are they Dalmatians?

Basic Level: Dogs

Script:
Wow! I just realized that if it's a dog, it has magnesium inside it! I'm going to look at some other pictures and ask you some more questions. For each of my questions you can tell me definitely yes, definitely no or there is no way to tell.

Script:
There are dogs. Do they have magnesium inside them?
These are not dogs. Do they have magnesium inside them?
These have magnesium inside them. Are they dogs?
These do not have magnesium inside them. Are they dogs?

Superordinate Level: Animals

Script:
Okay, I think I understand this information. If they are animals, they have magnesium inside the. Hhmmm…..I just have a few more questions. Just remember, for each of my questions you can tell me definitely yes, definitely no or there is no way to tell.

Script:
There are animals. Do they have magnesium inside them?
These are not animals. Do they have magnesium inside them?
These have magnesium inside them. Are they animals?
These do not have magnesium inside them. Are they animals?

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