Belief-revision in children and adults

by

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Abstract

Our beliefs about the world are prone to change as we encounter information that is incompatible with existing knowledge. Prior research has dominantly focused on children's deference to new information, when this information defies their existing perceptions and intuitions. However, the differential weight children attribute to various beliefs in their knowledge set when the new information calls for revision has been underexplored. This dissertation aims to expand our understanding of the reasoning process underlying children's belief-revision. Do some beliefs have privileged status in children's representation of the world, therefore making them more resistant to revision than others?

Findings presented in Chapter 2 showed that 5-, 7-year-old children and adults were equally likely to revise beliefs based on generalizations (e.g., All of Sophia's balls are dotted) and beliefs based on observations (e.g., Sophia brings a ball from her box to the table) about a particular entity when faced with inconsistent evidence (e.g., The ball on the table is striped). These results failed to replicate earlier findings showing a robust preference among 7-year-old children and adults to retain generalizations (e.g., All knights of King William wear a white hat) and instead to revise particular observations (e.g., This knight wears a black hat).

In Chapter 3 I addressed the possibility that category generalizations have a privileged status specifically when they convey essential, non-accidental aspects of the category rather than non-essential, accidental aspects. The results from Chapter 3 provided partial support for the differential weight 4- to 7-year-old children assign to essential and non-essential beliefs about a novel category. Overall, children revised their beliefs randomly. However, an analysis of performance by trial showed that children did not readily revise their initial beliefs based on the essential property of the novel exemplar in the first trial.

Taken together, these studies suggest that when incorporating new information into their existing knowledge, adults, and children between the ages of 4 to 7 years do not attribute a privileged status to their beliefs about category generalizations, not even when these are based on essential properties. Possible implications of children's flexibility in revising existing beliefs are discussed.

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General Introduction

1.1 Background

In a dynamically changing world, our existing knowledge is inevitably susceptible to reconstruction. In some situations, the change could be trigged by the evolving world which requires us to keep our knowledge up to date. For example, although it was correct at a specific point in time to believe "Coronavirus is an epidemic observed only in Wuhan, China", this belief soon became outdated. In other situations, we change our beliefs not as a result of the evolving aspects of the world but because our existing beliefs about some static aspect of the world turn out to be incorrect or incompatible with new information we encounter. As an example, the accumulation of empirical evidence for the sphericity of the earth has eventually led to the revision of the dominant belief that the Earth is flat. The current research focused on this latter type of change and examined children's revision of their prior beliefs in light of new evidence. How do children reconcile new evidence with their existing knowledge when it leads to some inconsistency in their belief set? Do some beliefs have privileged status in children's representation of the world and, as a result, are they more resistant to revision than others?

Prior developmental research has predominantly examined children's belief-revision in terms of their deference to new information, mostly presented in the form of verbal testimony. Typically, children's claims based on their observations or intuitive knowledge (e.g., where they think an object is hidden or what they think an ambiguous looking stimulus is) are pitted against conflicting verbal testimony and children have to make a choice that relies on one or the other. However, our beliefs about entities and events in the world are not formed in isolation. Instead, for any particular entity, we hold a set of specific beliefs which are interconnected with one another as well as with more general beliefs about the physical and social world. Therefore, prior research, with a focus on children's weighing of their own knowledge in relation to information they hear from others, did not account for the changes in children's existing beliefs about a particular entity that new information might lead. Belief-revision is defined as deciding which of several initially accepted beliefs to disbelieve, when new evidence presents a logical inconsistency with the initial set (Elio & Pelletier, 1997; Peppas, Nayak, Pagnucco, Foo, Kwok,

& Prokopenko, 1996). In this sense, the current work aims to contribute to the literature by expanding our understanding of the reasoning process underlying children's belief-revision.

This dissertation addresses children's reasoning strategies when belief revision occurs, by examining the type of prior beliefs that children change when new evidence leads to inconsistency in their belief set. I first introduce work to date on children's and adults' belief-revision. I then briefly review the development of children's deductive reasoning and category knowledge with a focus on how they are involved in the belief-revision process. I conclude the introduction with an overview of my research questions and methods.

1.2 Belief-revision in children

Children's formation and revision of beliefs about the world have been studied in different lines of research. On one hand, research on science education has focused on conceptual change by tracking children's beliefs about the causal structure of the physical and biological world across development. The research has shown that children's naïve theories (e.g., in physics) and misconceptions gradually change through direct instruction and exploration (Chi, 2008). For example, in the physical domain, children as young as 5-years can learn complex scientific information about concepts such as gravity or buoyancy, and more importantly revise their existing misconceptions about them when provided with rich conceptual explanations (Ganea, Larsen, Venkadasalam, in press; Venkadasalam & Ganea, 2018). The existing evidence in this line of research provides us with a relatively comprehensive knowledge base about the underlying mechanisms of conceptual change, by highlighting the importance of different kinds of input (anomalous evidence vs. alternative theories) in leading children to revise a strongly ingrained naïve belief about the world (Posner, Strike, Hewson & Gertzog, 1982; Potvin, 2013; Shtulman, 2017).

Another growing line of research on belief-revision examines children's processing and evaluation of counter-intuitive and counter-perceptual information conveyed through verbal testimony (see Lane, 2018 for a review). The majority of studies in this area focused on the age at which, and necessary conditions under which, children are likely to endorse or reject others' claims which conflict with their own perceptions or concepts. Evidence shows that preschool age children revise their initial beliefs about the identity of ambiguous objects, the eating behavior of novel species, and the contents of a hiding box based on others' counter-perceptual claims (Chan

& Tardif, 2013; Jaswal, 2004; Jaswal & Markman, 2007; Bernard, Harris, Terrier, & Clément, 2015; Ma & Ganea, 2010; Ronfard, Lane, Wang, & Harris, 2017; Ronfard, Chen, & Harris, 2017; Ganea & Harris, 2010; Rakoczy, Ehrling, Harris, & Schultze, 2015). However, when these claims run counter to children's normative beliefs or their intuitive concepts about the causal structure of the world, like non-normative but plausible phenomena (e.g., someone walking through fire or the idea of blue applesauce), the findings reveal a strong resistance among children younger than 8 years of age in adjusting their beliefs (Lane & Harris, 2014; Woolley & Ghossainy, 2013; Shtulman, 2009; Lane, Ronfard, Francioli, & Harris, 2016). The developmental difference fades away though with other type of counter-intuitive claims; 3- to 8-year-old children reject ideas that are inconsistent with their naïve theories about the causal structure of the world (e.g., the idea of a dog transforming into a cat or a ball going through a solid wall) (Lane & Harris, 2015).

These investigations detail the developmental trajectory of belief-revision in terms of children's decision as between their naïve theories and intuitive knowledge and contradictory evidence. More specifically, the focus so far has been on the factors influencing children's tendency to readily accept or reject claims that defy their own observations or knowledge. In this respect, prior research falls short of revealing the reasoning process involved and cannot speak to what inferences children make when they decide between their existing knowledge and new information. As a remedy, Chapter 2 in the current work, utilized the belief-contravening paradigm, widely used in research with adults, which allows for an examination of what changes take place in existing beliefs when individuals incorporate new evidence. The next section details the structure of this paradigm and summarizes relevant findings in regards to how adults reason when they revise their beliefs.

1.3 Belief-revision in adults: Belief-contravening problems as a way to reveal the reasoning behind

The way that adults reason and make inferences when evidence conflicts with prior beliefs and the factors influencing the belief-revision process has been studied extensively, both from a philosophical and a psychological perspective (Peppas et al., 1996; Elio & Pelletier, 1997; Liberatore, 2000; Bryne & Walsh, 2002). Unlike most of the developmental work, belief-revision research with adults has gone beyond yes-no paradigms that simply examine whether

revision occurs or not and asked how this process is achieved. To do so, research with adults has used belief-contravening problems to identify the underlying reasoning strategies involved in the reconciliation of new evidence in an existing belief set (Rescher, 2007; Elio & Pelletier, 1997). Belief-contravening problems represent our knowledge about a particular entity/event as a set of believed propositions, and rest on the principles of deductive reasoning. In a widely used example paradigm, participants first read a brief fantasy story about two kings (e.g., King William and King Igor) and the identifying feature of knights working for them (e.g., wearing a white vs black hat, respectively). After reading the passage, the belief-revision task begins by presenting participants a general and a particular premise, and the conclusion that follows from these two premises about the target entity given the background story:

(a) All knights of King William wear a white hat. (general premise, $p \rightarrow q$)

(b) This knight here wears a black hat. (particular premise, not q)

(c) This knight works for King Igor. (not p)

An inconsistency is created in this belief set by asking participants to assume that a counterfactual premise is true, e.g., (d) This knight works for King William (p). Following the inconsistency, participants are asked which of the previous premises they prefer to revise in order to incorporate the counterfactual premise in their existing belief set. They are presented with two options: 1) revise the general premise, (a1) Knights of King William can also wear a black hat, or 2) revise the particular premise, (b1) This knight here wears a white hat. With this propositional structure, belief-contravening problems are considered as an efficient way to explore which of their existing beliefs individuals revise to resolve the inconsistency caused by new evidence in their belief set.

The existing findings about which of their prior beliefs (general vs particular premise) individuals prefer to revise in these belief-contravening problems are mixed. There is some evidence showing that individuals are more likely to revise the general premise, i.e., modify the governing rule to accommodate the new evidence (Elio & Pelletier, 1997; Khemlani & Johnson-Laird, 2011; Politzer & Carles, 2001; Dieussaert, Schaeken, De Neys, & d'Ydewalle, 2000). Other findings suggest no distinct preference (Byrne & Walsh, 2002). There are also some studies showing that individuals are more likely to retain the general premise and instead revise

the particular premise in their solution to these problems (the so-called generalist solution: Revlin, Calvillo, & Mautone, 2003; Revlin, Calvillo, & Ballard, 2005; Swan, Chambers, & Revlin, 2013). Importantly, individuals' tendency for the generalist solution was not explained by the order of presentation; the privileged status of the general premise over the particular one was maintained even when it was presented second (Hasson, 2004).

From a logical point of view, revision of the general or particular premise is equally acceptable as both resolve the inconsistency (Revlin, Cate, & Rouss, 2002). However, research on reasoning and decision-making over the last decades highlights how human judgment can deviate from pure logical reasoning across a variety of situations (e.g., Evans, 2003; Kahneman, Slovic, Slovic, & Tversky, 1982). Dual-processing theory explains these fallacies of human judgment by proposing two qualitatively different cognitive systems underlying human reasoning: logical/analytical system and heuristic system (Evans & Stanovich, 2013a). The logical/analytical system requires deliberate, controlled processing which heavily relies on our limited working memory. On the other hand, the heuristic system is based on intuitions and stereotypical beliefs which facilitate fast and automatic responses. While the dual-processing account explains why a preference for revision of one premise over another can be observed when both revision options are logical, it does not predict a consistent belief-revision strategy determining whether the general or the particular premise should be favored.

Recently, a probability-based theory, was put forward to account for the inconsistent findings regarding individuals' belief-revision strategies. In contrast to earlier research which aimed to identify one single strategy individuals use when revising their beliefs, the probability-based theory argues that whether individuals revise or retain the general premise depends on the perceived probability of the general premise (Evans, Handley, & Over, 2003; Oaksford & Chater, 2001; Wolf & Knauf, 2008; 2009; Wolf, Rieger, & Knauff, 2012). Consider the following belief-contravening problem, "If Chris goes to work, then he will take the car; Chris does not take the car; Chris goes to work". When resolving the inconsistency here, people might reason, based on their prior experience and general trend, that the probability of taking the car when leaving for work is higher than the probability of not taking the car. As a result, the new information that Chris went to work but did not take his own car could lead people to generate an alternative possibility, e.g., that the car might have broken down. To the extent that an alternative possibility can readily be generated, people prefer to retain their high belief in the conditional

premise. As can be seen in this example, one's reasoning process in such a belief-revision situation would be subject to influence from a variety of factors such as one's background knowledge, the plausibility and believability of the premises, or the trustworthiness of the information source. These factors and others may explain the discrepancy in prior findings regarding individuals' belief-revision strategies across different studies.

The questions of which beliefs adults revise upon new evidence leading to inconsistency in their existing belief set and why that is the case are far from being resolved and beyond the scope of the current work. However, the existing findings shed light on some possible factors that might influence adults' reasoning strategies when reconciling new evidence with their existing beliefs. Given the scarcity of developmental research focusing on the reasoning processes underlying children's belief-revision, Chapter 2 in the current work adapted the belief-contravening paradigm to preschool and early elementary school age children. To date, there is only one study which tested 7-year-old children's belief-revision in this paradigm and showed that their reasoning strategies were similar to those of adults (Van Hoeck, Revlin, Dieussaert, & Schaeken, 2012). The main goal of Chapter 2 was to provide further empirical evidence for the similarity between children's and adults' reasoning when revising their belief and to test whether this similarity can be traced back to 5-years. The following two sections are devoted to a summary of research on preschool age children's ability to reason deductively and to represent category information, as these are two of the fundamental cognitive processes allegedly involved in the belief-contravening paradigm.

1.4 The development of deductive reasoning

Given the implied role of reasoning, especially deductive reasoning, in belief-revision, a brief review of the early development of this ability is warranted. Although several developmentalists, following Piaget, argued that logical and hypothetical reasoning do not emerge until middle childhood (e.g., Amsel, 2011; Kuhn, 2009; Markovits, 2013), there is research showing that under certain contexts and with some limitations, preschool age children make logical inferences based solely on presented premises.

Evidence shows that the ability to solve simple logical reasoning tasks requiring the deduction of a conclusion from a conditional proposition of the form "If p then q" (e.g., "If the wind is blowing, the flag on the pole is waving; The wind is blowing; Is the flag waving?") or

universally qualified propositions in the form of "All p are q" (e.g., "All bears have big teeth") emerges during the preschool years (Hawkins, Pea, Glick, & Scribner 1984; Kuhn, 1977). However, the content of the premises was found to affect how competent young children were in making correct inferences in these tasks. Young children find it difficult to override their existing knowledge when making inferences based on false (e.g., "All cats bark; Rex is a cat; Does Rex bark?") or unfamiliar premises, (e.g., "All togas are made of cotton; Andrew is looking at a toga; Is it made of cotton?"). This type of reasoning requires the ability to draw hypothetico-deductive inferences, which typically emerges beyond preschool. However, with some support, such as prompting children to engage in pretense by inviting them to temporarily accept the premises as working suppositions, or by presenting the premises in a dramatic, story-like intonation, even preschool age children have been found to make correct inferences in these situations (Dias & Harris, 1988, 1990; Harris, 2000; Leevers & Harris, 1999, 2000; Richards & Sanderson, 1999; Amsel, Trionfi, & Campbell, 2005).

In addition to the premise content, the propositional context influences young children's competence in deductive reasoning. It has been shown that children before the age of 6 have difficulty with conditional statements when they are based on arbitrary relational rules, e.g., "If there is a dog sticker on the lid, then there must be an orange in the box." (Chao & Cheng, 2000). The difficulty imposed by an arbitrary propositional context can be explained by children's reliance on their world knowledge; in situations where they can use their existing knowledge of the world, it might be easier for them to deduce the conclusion. For example, the conditional statement, "If the wind is blowing, the flag on the pole is waving" is in line with what children know about the physical workings of the world. Similarly, given their daily experience with conditionals in the form of permission rules (e.g., "If you finish your plate, you will get ice-cream"), young children are more proficient in their reasoning about conditionals within a pragmatic context. An earlier study showed that 3- and 4-year-old children can successfully evaluate an action based on a permission rule, e.g., "You can play outside if you wear a coat", by deciding whether the necessary condition was met (Harris & Núñez, 1996). On the other hand, it is not possible to derive artificial relations between antecedent and consequent in a conditional statement, as in, "If there is a dog sticker on the lid, then there must be an orange in the box.", from one's world knowledge. This type of conditional statement requires hypothetico-deductive reasoning which, as discussed above, has a relatively protracted development.

In order to reveal the reasoning process underlying children's belief-revision, the tasks used in the current work relied on children's ability to make deductive inferences based on a set of specific beliefs which formed their knowledge about a particular entity. The content of the premises and the propositional context used in the current work were developed in light of the research reviewed above. In other words, considering the limits on children's emerging deductive reasoning ability, children were presented with tasks that involved familiar premises and a propositional context for which they could rely on their existing world knowledge. For instance, in the study presented in Chapter 2, 5- and 7-year-old children were asked to draw inferences about two categories of everyday objects with familiar features, e.g., dotted vs striped balls belonging to two characters. The study presented in Chapter 3 focused on 4- to 7-year-old children's inferences about familiar internal body parts and accessories that belong to two novel kind categories, e.g., two vs. three bones inside the body/purple vs yellow glasses. Besides the potential influences of premise content and pragmatic context on children's reasoning, it is important to take into account how children represent a category in relation to the status of various beliefs that form their category knowledge about a particular entity. Are some of children's category-based beliefs more perpetual and others more transient? Arguably, the differential status that children attribute to certain beliefs that form their category representations influences which of their existing beliefs children revise in the face of inconsistency. Accordingly, the section below will review research on children's category knowledge.

1.5 Children's category-based beliefs

Organizing individual experiences (e.g., seeing two butterflies in the backyard) into broad, abstract categories (e.g., butterflies) is a crucial aspect of human cognition which helps children to learn about and interact with the physical and social world in an efficient and adaptive manner. Research on children's category knowledge is relevant to questions about the reasoning that enters into their belief-revision at two levels: 1) What is the status of category generalizations in their representation of the world? Do children prioritize category generalizations over particular observations which pertain to a given category when revising their existing beliefs in light of new evidence (Chapter 2)? 2) What is the relative status of different types of information within category generalizations? Do children prioritize category generalizations based on essential properties over those based on non-essential properties (Chapter 3)?

In regards to the status of category generalizations in children's knowledge, there is evidence for their privileged status (See Cimpian, 2016 for a review). First, research shows that making generalizations about a category (e.g., "Bears have white fur") is a predominant way of reasoning for young children such that even when specifically provided information about quantified category sets (e.g., "All/some bears have white fur"), children tend to treat the information as a true generalization of the category (Hollander, Gelman, & Star, 2002; Brandone, Gelman, & Hedglen, 2015; Gelman, Leslie, Was, & Koch, 2015). Second, from an early age, children ask about categories. A longitudinal study focusing on parent-child conversations showed that 2- to 4-year-old children frequently refer to categories in their spontaneous speech (e.g., "Why babies can't play with children?") (Gelman, Goetz, Sarnecka, & Flukes, 2008). Another study showed that, regardless of the novelty of the information, 4- and 5-year-old children were more curious to receive information about a category (e.g., pangolins/frogs) than an individual (e.g., a particular pangolin/frog) (Cimpian & Park, 2014). Third, children's memory for category and non-category representations appears to be different: 4- to 7-year-old children were better at remembering newly learned facts about a category (e.g., dogs like to chase an animal called dax) than an individual (e.g., a particular dog likes to chase an animal called dax) after a delay (Cimpian & Erickson, 2012). More importantly, research has shown that children do not merely forget information about the individuals/non-category sets but instead misremember that information as a fact pertaining to the category (Leslie & Gelman, 2012). Lastly, children have an expectation that category information is conventional in the sense that it is known to other individuals in their cultural/linguistic community. For example, a study showed that 4- to 7-year-old children were more likely to extend their knowledge of unfamiliar features of a category (e.g., that tigers catch lots of ruminants) to other people than their knowledge of an individual (e.g., that a particular tiger catches lots of ruminants) (Cimpian & Scott, 2012). Together this evidence suggests that category representations outweigh non-category representations in children's knowledge set. This raises the question of whether category generalizations would be more resistant to revision than individual observations when new evidence creates an inconsistency in children's existing belief set, which is addressed in Chapter 2.

A related aspect of children's category representations concerns whether children attribute differential value to the various types of information that pertain to their category

representations. Psychological theories of the human conceptual system propose that our representation of a particular category (e.g., birds) includes generalizations about individual features of a representative entity such as its body shape, behavior and origin (e.g., Barsalou, Kyle Simmons, Barbey, & Wilson, 2003; McGregor, Friedman, Reilly, & Newman, 2002). This structure of category-based representations allows children to reason and draw inferences about novel entities and situations that they encounter. Starting as early as 2 years of age, children understand that a natural category governs some properties that are potentially shared by all members of the category (See Gelman & Meyer, 2010 for a review). For example, children assume that certain biological properties of cats, such as having lungs, having four legs, or meowing are potentially true of all individual members of the cat category. Based on this assumption, when they learn about a new property of an individual member, young children extend this property to all other members of the category – a cognitive process called inductive generalization. However, not all sorts of properties are generalizable. For example, idiosyncratic information about an individual such as a spot on the tail of your friend's cat is not the sort of property that is expected to be present in all members of the category. Children rely on linguistic structures, especially the generic form (e.g., "Cats meow"), to decide when a property has an inductive potential. Comprehension and production of generic language emerges as early as 2.5 years (See Gelman & Roberts, 2017 for a review). For example, a study showed that children as young as 30-months are sensitive to the linguistic cues that afford induction; they were more likely to generalize an atypical property to other category members when they heard generic language, e.g., "Blicks drink ketchup" than when they heard non-generic language, e.g., "These blicks drink ketchup" (Graham, Gelman, & Clarke, 2016).

Despite the inductive generalization that generic language affords, it has been shown that children do not represent all categories alike. They differentiate between kinds (tiger) and arbitrary categories (white things) and attribute greater inductive power to the former which denotes a natural category at the basic level (Gelman & Waxman, 2007). Even within kind categories, it has been shown that preschool children's conceptual representation is domain-specific: they expect animal kind categories to be more coherent and homogenous compared to artifact kind categories, despite any perceptual similarity between the two (Brandone & Gelman, 2013). Furthermore, it has been shown that children are selective in the scope of their inductive inferences. Rather than generalizing all sorts of properties, they evaluate the quality of the

relation between the property and the kind. For example, preschool age children differentiate between properties that bear a principled connection to the kind (e.g., “Dogs have four legs”) and those that bear a statistical connection to the kind (e.g., “Barns are red”) (Haward, Wagner, Carey, & Prasada, 2018; Prasada & Dillingham, 2006; 2009; Prasada, Khemlani, Leslie, & Glucksberg, 2013). While children accept that both types of properties are true generalizations of their target categories, they appreciate that the properties with principled connections go beyond being a true generalization of the kind category and signify that the members of the kind have these properties by virtue of their being the kinds they are. Relatedly, a very recent study suggests that children’s ability to appreciate that there might be different causal structures determining how properties are connected to kinds emerges during the preschool years and develops through 9 years of age. Throughout this period, children’s category-based beliefs show increasing flexibility such that they differentiate between when the relation between a property and the kind category is naturally/biologically determined (e.g., “Ducks lay eggs”) and when it is cultural/socially constructed (e.g., “Boys like blue”) (Noyes & Keil, 2020). In sum, the existing evidence suggests that children are sensitive to the type of relation between an attribute and the respective category which leads to the question addressed in Chapter 3: do children prioritize certain types of information about categories when revising their prior beliefs in the face of inconsistent evidence?

1.6 Research questions and the present studies

Developmental research on belief-revision provides evidence of the flexibility in children’s construal of the world. We know that starting from the preschool years, children are open to endorsing counter-perceptual and counter-intuitive claims and revise their prior belief about an entity based on these claims (see Lane, 2018 for a review). However, we know less about the changes that take place in children’s broader set of beliefs pertaining to the target entity during revision. How do children decide which old beliefs to disbelieve when they incorporate the new evidence into their existing belief set? Among one’s set of beliefs about a particular entity, do some beliefs have higher status and hence are more resistant to revision than others? In the studies presented here, I examine the belief-revision process children engage in when they encounter information that is inconsistent with their prior knowledge.

Based on the reviewed research, beliefs might have differential status/resistance to revision in children's knowledge in two ways. First, they might differ in the extent to which they convey generalizable information about a particular entity. The belief-contravening paradigm, widely used in adult research, is a possible way to explore the relative status of generalizations vs observations in children's belief set about a category. There is evidence suggesting that adults and 7-year-old children favor general beliefs over particular beliefs, such that they prefer to revise the latter when new evidence leads to inconsistency in their belief set (Revlin, Calvillo, & Mautone, 2003; Revlin, Calvillo, & Ballard, 2005; Swan, Chambers, & Revlin, 2013; Van Hoeck et al., 2012). In Chapter 2, an adaptation of the belief-contravening paradigm was used to examine the status of generalizations in children's and adults' category representations. More specifically, the studies in Chapter 2 aimed to replicate and extend earlier findings regarding children's and adults' preference to prioritize category generalizations over particular observations which pertain to the category when revising their existing beliefs in light of new evidence.

Second, children might attribute differential status to their beliefs about a category to the extent that the information conveyed bears a principal connection to the category. The reviewed research on children's category representations indicates that children do not weigh all true generalizations of a category the same; they understand various causal mechanisms underlying the relation between attributes and the respective categories (Haward et al., 2018; Noyes & Keil, 2020). Chapter 3 asks whether children's reasoning about which old beliefs to revise are informed by their understanding that some attributes might connect to the category at a deeper level. More specifically, this chapter examines whether children prioritize essential beliefs over non-essential beliefs when new evidence is incompatible with what they initially believed to be true.

Chapter 2
Do children and adults privilege generalizations over observations when revising their beliefs?

2.1 Introduction

Our knowledge of the world is subject to change as we observe or receive new information. In most cases, the integration of this new information into our existing knowledge is straightforward; we simply add it to what we already know about a certain entity. However, there are also cases where the new information might be at odds with what we already know, leading to an inconsistency within our prior world knowledge. In the latter case, how do individuals reason to resolve these inconsistencies and reconcile the new information with their existing set of beliefs? Developmental research on belief-revision has provided us with a relatively good understanding of whether children believe in information that defies their own knowledge, perception and intuitions (Harris, 2012) and when (i.e., under what conditions) they revise their prior beliefs (see Lane, 2018 for a review). Less focus has been devoted to the reasoning process behind their belief-revision. The main goal of the current research is to fill this gap by examining how children incorporate new evidence into their existing belief sets, in other words, which of their prior beliefs children choose to revise and which of them they retain when they encounter information inconsistent with what they previously believed to be true.

There is corroborating evidence that children's formation and revision of their beliefs is a rational process: children do not believe new information indiscriminately and readily revise their existing beliefs (see Sobel & Kushnir, 2013). Whether their beliefs will be influenced by new information depends on the strength/robustness of their existing knowledge and beliefs relative to that of new information, and the degree of conflict between the two (Bridgers, Buchsbaum, Seiver, Griffiths, & Gopnik, 2016; Chan & Tardif, 2013; Ganea & Saylor, 2013; Galazka & Ganea, 2014; Jaswal, 2004; Lane, Harris, Gelman, & Wellman, 2014; Lane & Harris, 2015; Rakoczy et al., 2015). However, previous research cannot speak to how children reason and what inferences they make when they revise their existing beliefs mainly because the paradigms used in these studies did not reflect the fact that children's knowledge is represented as a set of beliefs, and hence their belief about a particular entity is presumably tied to reasoning about a broader set of beliefs about how the world is.

In a typical paradigm, children are required to decide between two conflicting sources of information; children's belief based on their own observation is pitted against verbal testimony which is inconsistent with this observation. For example, children are asked to categorize a hybrid animal with 75% cat-like features and 25% dog-like features (Jaswal, 2004). Then, children are told by an informant that the animal belongs to a category that does not conform to what the child initially said (e.g., if the child classifies the animal as a cat, the informant tells them "It is a dog"). Following this new evidence which conflicts with children's initial categorization, children are asked an inference question about the animal, e.g., whether the animal would bark or meow. If children answer the inference question based on the informant's categorization (e.g., "It barks") rather than their initial categorization (e.g., "It meows"), their response is taken as evidence that children revised their beliefs about the identity of the animal. Thus, the question tested in this type of paradigm is about children's decision between what they know and a new piece of conflicting information; do children override what they see in front of their eyes/what they themselves judge to be true at the beginning in favor of the new information conveyed through verbal testimony? However, this type of paradigm does not tell us much about the inferences children derive and what changes they make in their prior beliefs when incorporating the inconsistent evidence in their existing knowledge. Which existing beliefs do children initially use to conclude that the hybrid animal is a cat, and which of these existing beliefs that aided children to conclude that "It is a cat" are revised when they were informed that it was a dog?

In other words, children presumably engage in some reasoning initially, before concluding that the hybrid animal belongs to the "cat" category, based on what they already know about the perceptual features of cats (e.g., beliefs that cats have relatively small faces, that they have whiskers, etc.) and the extent to which these perceptual features are present in the target animal. When children revise their initial categorization, it is not clear whether they also revise any of the prior beliefs that helped them to identify the animal. For example, did they revise their general beliefs about what cats and dogs look like, ("Some cat-looking animals might be dogs") or did they revise their belief about their particular perceptual experience ("This animal is not what I see/what it looks like")?

I argue that belief-contravening problems which represent knowledge about a particular entity/event as a set of believed propositions could be a potential paradigm to investigate

children's reasoning when they reconcile new evidence with their existing beliefs in the face of inconsistency. To our knowledge, only one study so far has utilized belief-contravening problems developmentally (Van Hoeck et al., 2012). In this study, 7-year-old children and adults were presented with short stories that were accompanied by pictures. Each story started with the introduction of two agents and the critical properties of some objects that belong to these agents (e.g., "All knights of King William wear a white hat"). Then, participants were presented a premise (e.g., "This knight here works for King William") and a conclusion that would logically follow from the previous set of premises (e.g., "This knight wears a white hat") In the critical phase, children were prompted to engage in counterfactual thinking, i.e., represent a new claim which created an inconsistency within their existing belief set (e.g., "Let's pretend that the knight here wears a black hat") and next asked whether they would revise the general premise (e.g., "Knights of King William can also wear a black hat") or the particular premise (e.g., "This knight here works for King Igor") to resolve the inconsistency.

The findings revealed a robust tendency towards revising the particular premise, the so-called generalist solution among both adults and 7-year-old children. Overall, around 80% of the time, children and adults revised the belief that "This knight here works for King Igor" (the particular premise) in order to resolve the inconsistency between the counterfactual premise and the existing belief set. Given the fact that both revision options in these belief-revision problems lead to logically valid solutions, the intriguing question is why would individuals prioritize retention of the general premise?

Arguably, one possible mechanism underlying belief-revision is counterfactual reasoning (Revlin et al., 2003). According to this view, when individuals are presented with new evidence that contradicts what they know, they represent a nearest possible world where this evidence might be considered to be a true assumption and make inferences within this nearest possible world using this assumption (i.e., we represent a possible world in which "This knight works for King William" holds true). According to David Lewis' theory of Possible Worlds, beliefs in the nearest possible world are organized hierarchically; they are ranked in terms of their degree of necessity (as cited in Swan, Chambers, & Revlin, 2013). Following this theory, when there is a need to decide which old beliefs to retain and which ones to revise, existing beliefs are evaluated in terms of their relative necessity. For example, in the case of the above-mentioned scenario, the general premise, "All knights of King William wear a white hat" which conveys information

about the entire target category is more informative and generalizable than the particular premise, “This knight here wears a black hat”. With this reasoning, the general premise would be ranked higher in terms of the relative necessity and hence would resist revision. Thus, individuals presumably reason as follows, “A knight working for King William should be wearing a white hat.” and choose the option “This knight here wears a white hat” in order to resolve the inconsistency between the counterfactual premise and their existing belief set. In this sense, the evidence from Van Hoeck et al. (2012) is in line with the predictions of the Theory of Possible Worlds. Moreover, it suggests that the adult-like performance observed among 7-year-old children can be explained by their developed ability to reason counterfactually (Beck, 2016; Beck & Riggs, 2014; Nyhout & Ganea, 2019).

The main goal of the current research is twofold: 1) to provide further evidence for children’s and adults’ preference for retaining general statements over particular statements when incorporating new information inconsistent with prior beliefs, 2) to reveal when in development children begin adopting the reasoning strategies used by older children and adults. In Experiment 1, I adapted the paradigm used by Van Hoeck et al. (2012) with 7-year-olds to examine whether 5-year-old children use similar belief-revision strategies as 7-year-old children and adults. Research has provided substantive evidence for the emergence of counterfactual reasoning (Harris, German, & Mills, 1996; German & Nichols, 2003; Nyhout & Ganea, 2019) and syllogistic reasoning based on false/fantasy premises (i.e., premises which are incongruent with real-world knowledge) during the preschool years (Hawkins et al., 1984; Leevers & Harris, 1999; 2000). Therefore, if counterfactual thinking is the underlying mechanism for belief-revision in response to incompatible evidence as argued by some researchers (Revlin et al., 2005; Van Hoeck et al., 2012), then I would expect that 5-year-olds, like 7-year-olds and adults, prefer to retain general premises but revise particular premises when new evidence contradicts what they initially believed to be correct. Experiment 2 is a replication study in which the belief-contravening problems used in Van Hoeck et al. (2012) were used to test adults’ reasoning strategies when revising their beliefs.

The current studies were conducted in Turkey with native speakers of Turkish. There is some research suggesting cultural and linguistic variation in various aspects of cognition (See Varnum, Grossman, Kitayama, & Nisbett, 2010 for a review). In fact, a study showed different developmental trajectory for false belief understanding for speakers of languages with explicit

terms (e.g., Turkish and Puerto Rican Spanish) and those without explicit terms (e.g., English and Brazilian Portuguese) (Shatz, Diesendruck, Martinez-Beck, & Akar, 2003). In this sense, a possible consideration is whether there would be cross-linguistic or cross-cultural differences in belief-revision process. However, for "false belief", there is a special grammatical structure in Turkish which differentiates between "think/believe" and "falsely think/believe" which might facilitate children's sensitivity to the distinction between true and false belief early on. On the other hand, with regards to the grammatical structure utilized in the belief-contravening paradigm, there is no obvious difference between Turkish and English that might affect the way children and adults reason. Moreover, the content of the belief-contravening problems used in the current studies (e.g., pattern on balls, color of knights' hat) do not have any unique characteristics that would be considered to pertain to a specific cultural convention. Therefore, I did not expect any cultural or linguistic variation in the current studies.

2.2 Experiment 1

The goal of this experiment was to investigate whether 5-year-old children show a tendency to favor general premises over particular premises when revising their existing beliefs in the face of inconsistent evidence, similar to 7-year-old children and adults. The belief-contravening paradigm used by Van Hoeck et al. (2012) was adapted and simplified in several aspects to make it appropriate for 5-year-old children. First of all, shorter narratives were used to decrease the cognitive load and memory-related errors. The pilot data in the earlier study showed that 5- and 6-year-old children had difficulty remembering the details of the narratives and had to be excluded due to incorrect responses in memory check questions (Van Hoeck et al., 2012). Second, the content of the narratives was modified so that the entities mentioned in the narratives were more familiar for younger children. For example, rather than introducing a narrative about Kings and their knights, narratives about daily life situations and familiar objects (e.g., "All of Chloe's balls are striped") were used to make it more accessible for younger children, and hence support their ability to track the main premises laid out in the narrative. When developing the content, special attention was devoted to the ease with which beliefs were depicted using visual aids. The original paradigm used visual aids as well but these visual aids were not used systematically; while the general premise was accompanied with a picture in all cases, it was not possible to depict the counterfactual assumption and the particular statement in some cases. For example, when children were asked to pretend that a knight works for King William, or when

they were presented with the option to revise the particular premise that the person is a thief not a hero, it was not possible to use visual aids. It is possible that children more readily chose to revise a premise when it was only conveyed verbally relative to cases when it was also visually depicted in front of their eyes. In order to eliminate the possibility that the unsystematic use of visual aids might contribute to an elevated preference for the generalist solution, in the current study I carefully chose belief contents which could be fully depicted.

Similar to Van Hoeck et al. (2012), the belief-contravening problems were presented in the form of conditional syllogism (If p then q). Children were presented with two premises and asked to infer a conclusion based on these premises. However, the logical structure of these inferences differed in each problem. One of these problems was based on Modus Tollens inference where the second premise was denial of the consequent (not q). For example, given a conditional syllogism such as "If I study, then I will get a good grade", a premise denying the consequent, "I didn't get a good grade", would enable us to infer that the antecedent does not hold, i.e., it would be valid to claim "Therefore, I didn't study". The other belief-contravening problem was based on Modus Ponens inference where the second premise affirms the antecedent (p). In the Modus Ponens transformation of the example above, based on the premise, "I studied", we would be able to infer that the consequent holds true, i.e., "Therefore, I'll get a good grade". Previous work has shown that adults' tendency towards a generalist solution was more pronounced for Modus Tollens inferences (Revlin et al., 2001, Van Hoeck et al., 2012) while 7-year-olds were not found to be sensitive to the logical structure of the belief-contravening problems in their belief-revision (Van Hoeck et al., 2012). Thus, similar to 7-year-olds, I did not expect to see any differences in how 5-year-old children resolve different types of problems.

2.2.1 Method

2.2.1.1 Participants

The sample consisted of 38 5-year-old children (M_{age} = 65.7 months, 22 F), 22 (21) 7-year-old children (M_{age} = 88.5 months, 15 F) and 32 adults (M_{age} = 20.8 years, 16 F). An additional 7 children were excluded due to inattentiveness/uncooperativeness (n = 3), no clear response to the test questions (n = 1), not passing the control questions across all trials (n = 3). Children were noted as inattentive if they did not pay attention to the stimuli and/or did not follow the storyline (e.g., looking around or engaging in irrelevant conversation with the experimenter). Children

were recruited from private preschools and elementary schools in Turkey and through word-of-mouth. Adult participants were recruited among psychology major undergraduate students at Maltepe University in Turkey. Both children and adults came from families with middle to high socio-economic background. Demographic information was collected to ensure that the sample is representative of the population of interest (See Appendix A for the demographic information form). Typically developing children who heard Turkish at least 75% of the time at home were included. Atypical development was determined based on information given by the daycare/school counselor or the parent through the demographic information form. Adult participants went through an informed consent process. Parents gave their written consent for their children's participation before the study began. Adult participants received course credit for their participation. Children received a sticker for their participation.

2.2.1.2 Procedure

The experimental task consisted of 6 belief-contravening problems presented in two inference type: Modus Ponens (MP) and Modus Tollens (MT) which will be further explained below. At the start of the task, children were given a brief introduction to these problems: "Now we're going to think about some little stories together. Some of the things in the stories may sound a bit funny, but we are going to think about what things would be like if all the things in the stories were true."

The belief-contravening problems were presented in the form of vignettes in which children learned new information about a category of objects that certain people own ("All of Chloe's balls are striped"). In order to reduce the memory load and support children's representation of the verbal content, the vignettes were accompanied by visual cues which were kept in front of the child throughout the task. Table 2.1 depicts the general structure of the task (See Appendix B for the complete set of the vignettes and the visual cues). The following phases varied as a function of the inference type. In MP problems, children were presented with a particular premise affirming the antecedent of the category information they initially heard, "Chloe brings a ball from her box to the table," and were asked to infer the critical attribute of the object, "Do you think the ball that Chloe brings from her box to the table is striped or dotted?". In MT, children were presented with a particular premise denying the consequent of the category information they initially heard, "One of them brings a dotted ball from her box to the table" and

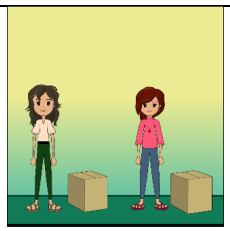
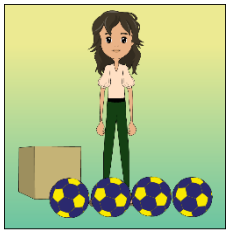
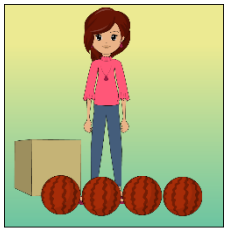
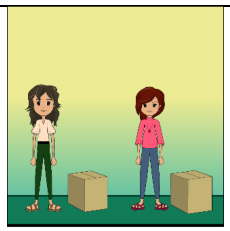
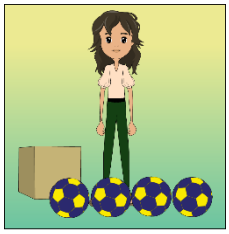
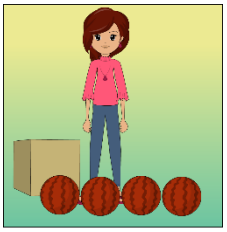
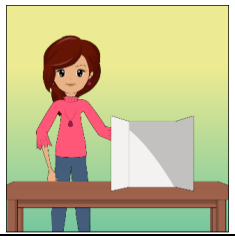
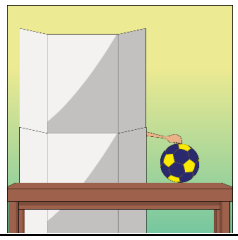
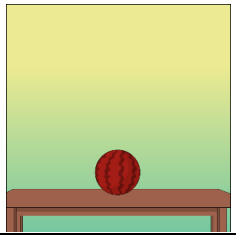
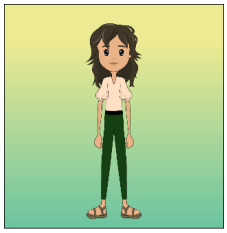
were asked to infer whom the object belongs to, “Who do you think brings the dotted ball from her box to the table? Chloe or Sophia?”. Previous findings suggest that children by 4 years of age can successfully make the correct inference in both logical structures (see Hawkins et al., 1984; Leevers & Harris, 1999; 2000). Participants who failed to make a correct inference were given feedback and their data for vignettes in which they failed to make a correct inference were discarded (7% of the trials among 5-year-olds, %3 of the trials among 7-year-olds, and 3% of the trials among adults).

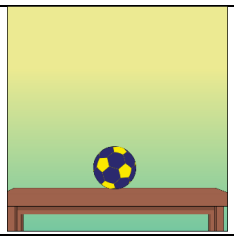
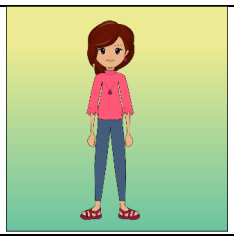
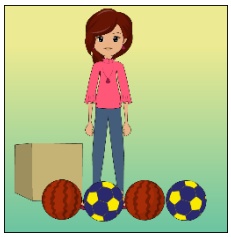
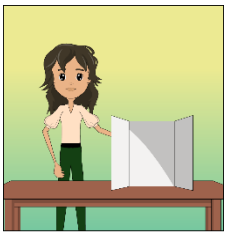
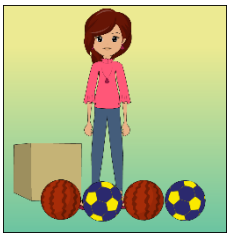
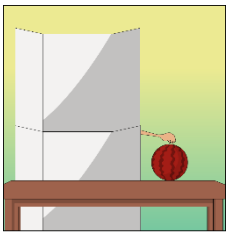
Next, the critical phase of the experimental task began. Children were asked to pretend the opposite of their inferred conclusion. In MP problems, children heard a statement about the object having the opposite attribute, “Let’s say that the ball Chloe brings from her box to the table is dotted!” while E put the corresponding picture on top of the previous one. In MT problems, children heard a statement about the object belonging to the other character, “Let’s say that it is Chloe who brings the dotted ball from her box to the table!” while E put the corresponding picture on top of the previous one.

This new evidence rendered the initial story they heard incoherent. The experimenter drew children’s attention to the incoherency (“Then, it does not fit with the rest of the story”) and the test phase began. Children were asked which of their previously held beliefs about this story they preferred to revise to make the story coherent again (“What should we fix/change in the story?”). Response options differed as a function of the inference type: 1) “We either change the story so that Chloe has dotted balls as well or we change it so that it is Sophia who brings a ball from her box to the table.” for MP problems, 2) “We either change the story so that Chloe has dotted balls as well or we change it so that the ball on the table is striped.” for MT problems. The experimenter placed two pictures depicting these two response options on the table and children’s preference between these two options was recorded.

Table 2.1 An example test sequence

	Modus Ponens	Modus Tollens
Introduction	Here is Chloe and Sophia. They have lots of balls inside their boxes.	Here is Chloe and Sophia. They have lots of balls inside their boxes.

	 All of Sophia's balls are dotted. All of Chloe's balls are striped.  	 All of Sophia's balls are dotted. All of Chloe's balls are striped.  
General premise	So, in the story, all of Chloe's balls are striped. [p → q]	So, in the story, all of Chloe's balls are striped. [p → q]
Particular premise	Chloe brings a ball from her box to the table. [p] 	One of them brings a dotted ball from her box to the table. [not q] 
Inference question	Do you think the ball that Chloe brings from her box to the table is striped or dotted? Correct answer: Striped [q] 	Who do you think brings the dotted to the table? Chloe or Sophia? Correct answer: Sophia [not p] 
Incompatible evidence	Let's say/assume that the ball Chloe brings from her box to the table is dotted! [E puts the following picture on top of the previous one]	Let's say/assume that it is Chloe who brings the dotted ball from her box to the table! [E puts the following picture on top of the previous one]

		
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we fix/change in the story? We either change the story so that Chloe has dotted balls as well or we change it so that it is Sophia who brings a ball to the table.   What do you think? Which part of the story we should change, this or this?[Pointing to the two possible options depicted on the pictures]	What should we fix/change in the story? We either change the story so that Chloe has dotted balls as well or we change it so that the ball on the table is striped.   What do you think? Which part of the tory we should change, this or this? [Pointing to the two possible options depicted on the pictures]

2.2.1.3 Coding and Reliability

During the test phase, participants were asked which of their existing beliefs they preferred to revise in order to reinstate consistency in the story, given the incompatible evidence, “Then, it does not fit with the rest of the story. What should we fix/change in the story?”. Participants were presented with two choice options to revise the story; the options differed as a function of the logical structure/inference type. In MP trials, choosing the option, “We either change the story so that Chloe has dotted balls as well…” was coded as “revision of the general premise” and choosing the option “…or we change it so that it is Sophia who brings a ball to the table”

was coded as “revision of the particular premise”. In MT trials, choosing the option, “We either change the story so that Chloe has dotted balls as well…” was coded as “revision of the general premise” and choosing the option “…or we change it so that the ball on the table is striped” was coded as “revision of the particular premise”.

Participants’ choice of the two test options was coded. Both pointing and verbal responses were counted as long as they clearly indicated preference for one of the test options. If participants’ initial choice was not clear (e.g., choosing both options/making an irrelevant choice), the test question was repeated. Data for trials in which participants did not make a clear choice upon repetition of the test question were excluded from the analyses (n = 3 5-year-olds).

If participants chose to revise the particular premise, they were categorized as adapting the so-called generalist solution and their response was coded as “1”. If participants chose the other option, their response was coded as “0”. As indicated above, participants received 3 MP trials and 3 MT trials, therefore their scores could range from 0 to 6.

A trained research assistant coded the whole sample offline, from recorded videos. A second research assistant coded 57% of the sample. The coders were blind to the study hypothesis. The interrater reliability was high for all trials, determined by Cohen’s κ ranging between 0.87 and 1.00 (all *p*s < .001). The coders resolved the disagreements through discussion.

2.2.2 Results

First, descriptive analyses were run to check for any effects of gender, block order and testing location on participants’ tendency to choose a generalist solution (See Table 2.2). Separate independent-samples t-tests showed that female and male participants had similar overall tendency for generalist solution (across six test trials); t (38) = -0.567, $p = .574$ for children and t (25) = 0.783, $p = .441$ for adults. Moreover, participants’ overall tendency for generalist solution did not significantly differ as a function of either block order (i.e., whether they received MP trials first); t (38) = 0.862, $p = .394$ for children and t (25) = -1.177, $p = .250$ for adults. Testing location (i.e., whether testing took place at home vs school) did not affect children’s overall tendency for generalist solution either; t (38) = 0.255, $p = .800$, (no descriptive analysis was run for adults since all adults were tested at the university).

Table 2.2 Percentage of trials (out of 6) with generalist solution across gender, test location and block order.

	5-year-olds		7-year-olds		Adults	
Gender	N	% out of 6 trials	N	% out of 6 trials	N	% out of 6 trials
Females	22	57%	16	60%	16	59%
Male	16	66%	6	61%	16	48%
Testing Location						
School	20	62%	16	63%	32	53%
Home	18	60%	6	52%	-	-
Order						
MP trials first	17	71%	15	59%	17	48%
MT trials first	21	52%	7	61%	15	59%

A Generalized Estimation Equation (GEE) with binomial distribution, logit-log link functions and independent covariance structures was used to accommodate the binary nature of the dependent variable and the presence of a within-subject factor (logical structure/inference type) in the data. The dependent variable was participants' revision choice (revision of the general premise vs particular premise) in any given trial. The predictors were age (5-year-olds, 7-year-olds, adults) and logical structure (MP vs MT).

There was no significant main effect for age, $p = .605$ or logical structure/inference type, $p = .384$, suggesting that on their own, age and logical structure/inference type did not influence the likelihood that participants preferred revision of general premises over particular premises.

Moreover, there was also no significant interaction between age and logical structure/inference type, $p = .482$.

Additionally, we tested whether participants' tendency for the generalist solution against chance separately for age groups and logical structures/inference types. Since there were 3 trials in each logical structure, the chance level for preferring a generalist solution in a given logical structure was taken as 1.5. Separate Wilcoxon signed-rank tests were conducted to accommodate the ordinal nature of the outcome variable. Participants did not choose a generalist solution at a rate significantly above chance levels in either age group or for either logical structure/inference type (all ps > .06).

Finally, as an exploratory analysis, we examined participants' choice in the first trial of a given logical structure/inference type. Because participants received 3 trials in each logical structure, there is a possibility that they might have shifted strategy across trials and hence examining the performance across 3 trials might not reflect their actual tendency for a generalist solution. Using two-tailed binomial tests, we compared the percentage of children and adults who chose the generalist solution on the 1st trial in each logical structure against chance (.5). Figure 2.1 shows the distribution of generalist solution across trials. The results showed that both children's and adults' choice of the generalist solution was at chance; $p = .15$ for MP trials and $p = .16$ for MT trials among 5-year-olds, $p = .50$ for MP trials and $p = .83$ for MT trials among 7-year-olds, $p = .19$ for MP trials and $p = .47$ for MT trials among adults. Table 2.3 shows trial-by-trial generalist solution frequencies and percentages for each test trial in a given inference type block.

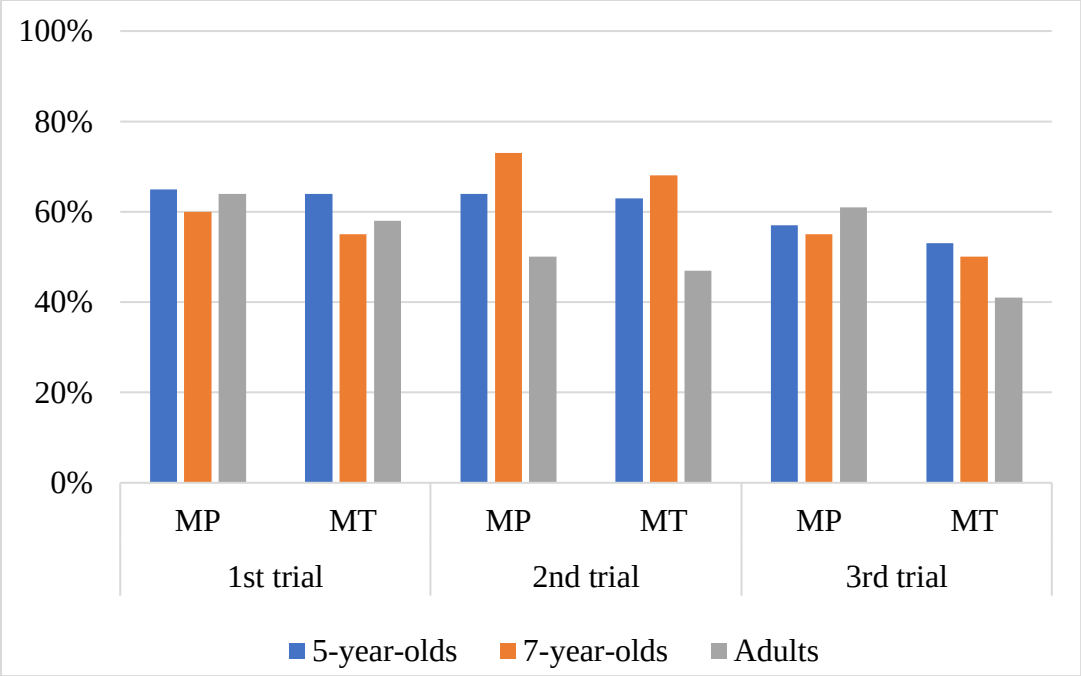


Figure 2.1. Percentage of participants who chose a generalist solution in each trial in a given block of inference type across age groups.

Table 2.3 Trial-by-trial generalist solution frequencies and percentages for each test trial by inference type blocks in Experiment 1

MP block first (n = 49)

		MP			MT		
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
All participants							
	%	62%	58%	60%	63%	63%	49%
	n	23/37	28/48	29/48	29/46	31/49	24/49
5-year-olds							
	%	82%	69%	71%	73%	77%	59%
	n	9/11	11/16	12/17	11/15	13/17	10/17

7-year-olds							
	%	46%	73%	47%	60%	73%	53%
	n	6/13	11/15	7/15	9/15	11/15	8/15
Adults							
	%	62%	35%	63%	56%	41%	35%
	n	8/13	6/17	10/16	9/16	7/17	6/17

MT block first (n = 43)

		MT			MP		
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
All participants							
	%	64%	64%	55%	54%	54%	46%
	n	27/42	27/42	22/40	21/39	23/43	19/41
5-year-olds							
	%	55%	60%	45%	53%	52%	47%
	n	11/20	12/20	9/20	9/17	11/21	9/19
7-year-olds							
	%	86%	71%	80%	43%	57%	43%
	n	6/7	5/7	4/5	3/7	4/7	3/7
Adults							
	%	67%	67%	60%	60%	53%	47%
	n	10/15	10/15	9/15	9/15	8/15	7/15

2.2.3 Discussion

The findings of Experiment 1 did not reveal a preference for the generalist solution among 5-, 7-year-olds and adults. All age groups chose to revise the particular premise around chance levels which does not conform with the Van Hoeck et al. (2012) finding that 7-year-old children and adults reason in favor of retaining the general information when faced with evidence that is inconsistent with their prior beliefs.

How can we explain this discrepancy? One possible explanation could be the absence of a coherent narrative in the current study. The original paradigm used a narrative so that the beliefs introduced were not arbitrary and did not lack a priori believability but rested on a coherent structure similar to law-like world knowledge (Van Hoeck at al., 2012; see also Revlin et al., 2005). However, the narrative used in the original paradigm did not actually support both revision options to the same extent; although the narrative involved a good amount of background information about the general premise (i.e., the identifying features of the knights working for two different kings), it did not tell participants much about the particular premise (i.e., the color of an individual knight's hat). In this sense, the narrative arguably helped to strengthen the representation of the general premise substantially relative to the information conveyed by the particular premise which appeared only in the test phase. Since the general premise was relatively more entrenched throughout the narrative, it is not surprising at all that the majority of children (and adults) resisted revising it. In the current study, I chose not to include a narrative in order to reveal whether there exists a preference for one type of belief over another when both are presented at the same level of entrenchment. Therefore, it is possible that in the absence of a narrative which supposedly helps propositions to be treated like real, law-like beliefs and natural semantic categories (Van Hoeck et al., 2012, p.411), individuals have no preference for prioritizing general premises over particular premises in their belief set.

Another possible explanation could be that in the original paradigm, the narrative was based on a highly stereotypical feature to identify the target category, e.g., good people wear white cloths whereas bad people wear black cloths. Thus, when children encountered new evidence, e.g., a good knight wearing a black hat, it is not surprising that children did not opt to revise the general premise, i.e., good knights of King William can also wear black hat, which would be contrary to the strong association between whiteness and goodness (e.g., Jacobs & Potenza, 1991). In other

words, I argue that the use of a stereotypical feature might have contributed to the entrenchment of the general premise to a greater extent than the premise, and hence made it more resistant to revision. Given the evidence for the influence of intuitive feelings and stereotypical beliefs on adults' as well as children's reasoning (Evans, 2003; Kahneman et al., 1982; De Neys & Vanderputte, 2011), the use of neutral features (e.g., two girls having differing type of balls: striped vs dotted) in the current study might explain the discrepancy in the findings.

However, the discrepancy in the findings can also be attributed to the influence of content. In the original paradigm the beliefs pertained to a fantasy world (two kings and their knights) rather than the real world. Reasoning about evidence inconsistent with prior beliefs in a fantasy context might be different from doing so in a realistic context. It is possible that fantastical stories prompt children to think about alternative possible worlds to a greater extent, which in turn might encourage them to easily revise their direct observation/what they see in front of their eyes and replace for example the black hat of an individual knight with a white hat. There is some suggestive evidence from adult studies that the belief-revision strategies adults use might vary depending on the degree of reality of the beliefs to be revised (see Swan et al., 2013 for a discussion). Thus, due to the realistic content of the beliefs used in the current study, it is possible that children and adults did not have any salient preference for one type of knowledge over another.

In sum, it is possible that some of the features of the original paradigm that we analyzed above might have boosted children's and adults' tendency to favor one solution over the other. However, because the current experiment did not systematically manipulate and test the effects of any of the factors mentioned above, I cannot rule out these possible explanations with the existing findings from Experiment 1. Therefore, Experiment 2 was conducted as a replication study in order to test the reliability of the observed preference for the so-called generalist solution in the original paradigm.

2.3 Experiment 2

In the second experiment, the goal was to reveal if a tendency to favor general premises over particular premises exists among adults when they revise their existing beliefs in the face of inconsistent evidence. In Experiment 1 several aspects of the belief-contravening problems used in Van Hoeck et al. (2012) were modified and the experiment failed to provide evidence for such

a tendency. In order to test whether the discrepancy in the findings is explained by these modifications, Experiment 2 used the original paradigm and aimed to replicate the earlier findings.

2.3.1 Method

2.3.1.1 Participants

The sample consisted of 49 adults (42 F) with a mean age of 25.5 years (Range = 18 - 41, SD = 7.01). Sixty-nine percent of the sample (n = 34) consisted of volunteer participants among psychology major undergraduate students at Maltepe University and 18% (n = 9) consisted of volunteer participants among high school teachers at a public high school in Turkey. The rest (13%, n = 6) were recruited through word-of-mouth and were university graduates with diverse professional backgrounds. The socio-economic status of the sample ranged from middle to high. All participants went through an informed consent process.

2.3.1.2 Procedure

The belief-revision task was directly adapted from Van Hoeck et al. (2012) such that the narratives and the questions were translated into Turkish. The only difference was that in the current study we implemented a paper-and-pencil procedure given that our sample consisted of only adults (as opposed to Van Hoeck et al. who tested children alongside) who are shown to be capable of following the information in this paradigm in the absence of visual aids (Revlin et al., 2005).

Participants first read a narrative, then they answered memory check questions about the critical information conveyed in the narrative ("What was the colour of the hats of the knights of King William/King Igor?"). Memory questions were followed by a belief-contravening problem where participants were presented with a general premise, a particular premise and the conclusion that is derived from these premises:

2a. "So, in the story all good knights of King William wore a white hat."

2b. "This knight wears a black hat."

2c. "This means that this knight works for the bad King Igor."

Then participants were asked to assume that the derived conclusion is not true with the goal of creating an inconsistency in their existing belief set:

"Let's pretend now that [literally: Let's now do as if …]"

2d. "….this knight fights with the good king, King William [instead of with the bad king]."

In order to make sure that the participants actually detected an inconsistency following this manipulation, they were asked a check question, "Now the story is not correct anymore… Can you tell me why?".

The last phase involved the test question in which participants were asked to make a decision between two options:

"We have two options to solve this problem, to make it correct again."

a. "Either the knights of King William can also wear a black hat now."

b. "Or we give this knight a white hat."

"Which option do you chose, do you prefer?"

In addition, participants received a second check question asking them to explain how they thought their choice resolved the inconsistency, "Why is the story correct again?". Each participant received two narratives, one about Knights and one about Heroes. For each participant one of these narratives was followed by a belief-contravening problem based on Modus Ponens inference and the other one was followed by a belief-contravening problem based on Modus Tollens inference (See Appendix C). For half of the participants, one story appeared in Modus Ponens and the other story appeared in Modus Tollens. The other half were presented the reverse. The order in which each logical structure presented was counterbalanced.

2.3.1.3 Coding and Reliability

For the memory check questions, participants' written answers were coded as "correct" (1) and "incorrect" (0). None of the participants failed to correctly answer the memory questions. Participants' response to the first check question was particularly important as an inclusion criterion because their answer revealed whether the manipulation worked. If participants did not

detect an inconsistency in their belief set given the negation of the conclusion derived from the premises, their choice for revision of the general vs particular premise would be not interpretable. Participants who noted that there was no inconsistency (n = 4) did not make a choice in the test question for both trials and hence their data were not included in the analyses.

At the test phase, participants were asked which of their existing beliefs they preferred to revise in order to reinstate consistency in the story, given the incompatible evidence, "We have two options to solve this problem, to make it correct again". Participants were presented with two choice options to revise the story; while the option based on the revision of the general premise was the same, the option based on the revision of the particular premise differed as a function of the logical structure/inference type. In MP trials, choosing the option, "a. Either the knights of King William can also wear a black hat now." was coded as "revision of the general premise" and choosing the option, "b. Or this knight here works for bad King Igor" was coded as "revision of the particular premise". In MT trials, choosing the option, "a. Either the knights of King William can also wear a black hat now." was coded as "revision of the general premise" and choosing the option, "b. Or we give this knight a white hat." was coded as "revision of the particular premise".

Participants' choice of the two test options in each trial was coded. If participants chose to revise the particular premise (Option b), they were categorized as adapting the so-called generalist solution and their response was coded as "1". If participants chose to revise the general premise (Option a), their response was coded as "0". Because participants received one belief-contravening problem in each inference type, each participant had two scores in total, one for the MP trial and one for the MT trial. Two participants who noted their disagreement with the "good-white vs bad-black" association conveyed by the general premises embedded in the narrative and hence did not make a choice in the test questions were excluded from the analyses.

Lastly, participants' response to the second check question, "Why is the story correct again?", was coded in terms of whether participants were able to provide an explanation supporting their decision to revise the general vs particular premise in the forced-choice test question.

The data were collected using a paper-pencil procedure. Participants' data were entered into the data spreadsheet and coded by the main researcher.

2.3.2 Results

First, descriptive analyses were run to check for any effects of gender and trial order on participants' overall tendency (across two trials) to choose a generalist solution (See Table 2.4). Due to the imbalance in the proportion of female/male participants in the study, a Fisher's Exact test was used to examine the effects of gender. The response pattern did not differ as a function of gender, $p = .33$. In addition, a chi-square test showed no effect of trial (i.e., whether they received MP trial first), $\chi 2\ (2, N = 49) = 0.160$, $p = .92$.

Table 2.4 Distribution of response patterns across gender and trial order

	Revision of general premise in both trials (0/2)	Inconsistent across trials (1/2)	Revision of particular premise in both trials (2/2)
Gender			
Female	17	7	18
Male	5	0	2
Trial Order			
MP trial first	11	3	9
MT trial first	11	4	11

The main research question of the current study was to investigate whether adults showed a preference to revise the particular premise (i.e., so-called generalist solution) in order to resolve the inconsistency in their belief set. The generalist solution was observed among 53% of the participants (26 out of 49) in MP trials, and among 43% of the participants (21 out of 49) in MT trials. Two separate binomial tests showed that neither proportion was significantly differed from chance ($p = .78$ for MP and $p = .39$ for MT).

Because inference type was manipulated within-subjects, we also examined the response pattern at the individual level. As shown in Table 2.5, participants' choices across the two trials (MP vs MT) were consistent. Forty-one percent of participants consistently chose to revise the particular premise across both inference types while 45% of them consistently chose to revise the general

premise across both inference types. A McNemar test showed that participants were equally distributed across two response options in both trials, $p = .13$

Table 2.5 Distribution of individual participants' responses across trials.

		MT trials	
		Revision of particular premise	Revision of general premise
MP trials	Revision of particular premise	20	6
	Revision of general premise	1	22

Lastly, we examined participants' explanations of the revision choice they made. Overall, participants' explanations confirmed that their choices were not random but were informed by how much they accepted and rejected the situation built through the story. All participants who favored the generalist solution, claimed that they preferred to resolve the inconsistency by revising the particular premise so that the situation was in line with the white vs black/good vs evil distinction stated in the story. On the other hand, among those who favored the particularist solution, the majority of the participants (70%) claimed that they preferred to revise the general premise because the distinction between good vs evil/white vs black did not make sense. The remaining participants chose to revise the general premise but also claimed that their choice did not really fix the inconsistency because the inconsistency resulted from the way the story associated good vs evil with white vs black in the first place.

2.3.3 Discussion

Experiment 2 failed to replicate earlier findings; I found no reliable preference among adults for the generalist solution. Even with all the features of the original paradigm maintained, adults were equally likely to revise the general and the particular premise when presented with evidence that is inconsistent with their existing belief set. The replication study used the stimuli and

followed the procedure as reported by Van Hoeck et al. (2012) which makes it difficult to generate a possible explanation for the discrepancy in the findings. Given that the current studies were conducted with native speakers of Turkish, the storyline was translated to Turkish by the researcher who is also a native speaker of Turkish. Van Hoeck et al. (2012) tested Dutch children and adults, as well as English adults as a comparison group. Although quite unlikely, it is possible that some extraneous factors such as nuances in the framing/wording of the stimuli or the task instructions, not reported in the paper, might have led to variation in individuals' reasoning. A more plausible explanation may have to do with the reliability and validity of the so-called generalist solution, which is discussed further in the next section. The General Discussion is devoted to the interpretation of what the findings from Experiment 1 and 2 together suggest in terms of the reasoning strategies children and adults deploy when they are faced with evidence inconsistent with their existing beliefs.

2.4 General Discussion

The current research examined the reasoning strategies children and adults use during the integration of new information into their existing knowledge when this information is incompatible with their prior beliefs. In order to examine this research question, the current studies used belief-contravening problems which represent individuals' knowledge about a particular entity as a set of propositions and hence reveals which of the existing beliefs individuals are likely to revise when they incorporate the new evidence.

Experiment 1 asked when in development children begin adopting the reasoning strategies used by older children and adults. An earlier study using belief-contravening problems showed that 7-year-olds, similar to adults, have a strong preference for retaining their beliefs about general information ("All knights of King William wear a white hat") and instead revise their beliefs about particular observations ("This knight here works for King William") when they encounter inconsistent evidence ("This knight here wears a black hat") (Van Hoeck et al., 2012). Experiment 1 modified several features of this belief-revision paradigm in order to: 1) ensure that the observed preference was not due to some features of the paradigm; and 2) simplify the procedure to make it accessible to 5-year-old children. The findings of Experiment 1 did not confirm the pattern observed among adults and children in the earlier study; no preference for revising the particular premise in favor of the general premise was found. In order to investigate

whether the null findings in Experiment 1 were due to the features of the paradigm that we modified; Experiment 2 was conducted by using the original paradigm in a direct replication study. This study focused only on adults and followed the exact procedure used in Van Hoeck et al. (2012). The findings of Experiment 2 failed to replicate the results of the previous study; 41% of the participants deployed the so-called generalist solution and revised the particular premise, while 45% of them revised the general premise across two belief-contravening problems. Thus, adults were equally likely to choose the general and the particular beliefs for revision. Moreover, individual participants were consistent in the strategy they used to reason when revising their beliefs regardless of the inference they were required to make; only 14% of the adults switched strategy across the two belief-contravening problems while the majority (86%) consistently chose one strategy (e.g., revision of the general premise) over the other.

The findings from Experiment 1 and 2 together lead to revisiting the initial question: Why should we expect a preference for the generalist solution in the first place? What is the advantage of retaining the general belief when we encounter new evidence that is inconsistent with our belief set?

While from a logical perspective, the decision about which belief to revise is arbitrary, the theory of Possible Worlds predicts that some of our beliefs might have higher status than others because they convey explanation, regularities or hypotheses about the physical and social world (Lewis, 1973, 1986 as cited in Swan et al., 2013). Therefore, beliefs that are organized at the higher levels of the hierarchy might be more resistant to revision compared to beliefs at the lower levels of the hierarchy. Following this prediction, since the general premise, e.g., “All knights of King William wear a white hat/All of Chloe’s balls are striped”, conveys information about some rule (wearing a white hat) that defines the target category, it should be registered at a higher level in one’s belief set. On the other hand, the particular premises (e.g., “This knight wears a black hat/Here is a dotted ball”), which convey facts, data or observations should be registered at a lower level in one’s belief set. However, the data from the current research did not support the predictions of the Possible Worlds theory.

The current findings could be interpreted such that children, as well as adults, relied on logical principles rather than evaluate the relative necessity/status of the beliefs in their belief set when solving the inconsistencies in the belief-contravening problems. Given that both revision options

are logically possible, the finding that adults were split across two groups (those who consistently chose to revise the general premise and those who consistently chose to revise the particular premise) (Experiment 2) render this explanation likely. Moreover, the almost half-half split suggests that there are individual differences in how adults interpret the belief-contravening problems. What individual differences could underlie adults' reasoning in these situations? As discussed earlier, the belief-contravening paradigm rests on deductive reasoning such that in order to resolve the inconsistency, individuals are required to make correct inferences based on the given information and their existing beliefs. More importantly, they need to understand the hypothetical nature of the conditional statement and what it entails. Research has shown that there is great variability in individuals' logical reasoning, not only in real-life situations but also in highly constrained laboratory conditions (See Markovits, Brisson, de Chantal, & Thompson, 2017 for a review). Therefore, it is possible that variability in individuals' logical reasoning skills might account for how they resolve the inconsistencies in belief-contravening problems. Exploring individual differences in belief-revision strategies is indeed an interesting research question for future studies.

A possible alternative explanation is that the general premises in Experiment 1 and 2 did not meet the criterion for a priori believability. Evidence from research with adults suggests that individuals' reasoning when revising their beliefs might be influenced by the believability of the given premises (Ball, Phillips, Wade, & Quayle, 2006; Calvillo, & Revlin, 2002; Hasson & Johnson-Laird, 2003). Although the argument behind the presence of a coherent narrative in the original paradigm was to attribute the general premise ("All knights of King William wear a white hat.") a law-like feature and hence increase its believability, Experiment 2 findings suggest that the narrative was not successful/sufficient in this manipulation. In fact, the anecdotal evidence from both experiments supports this possibility. Some participants explicitly rejected the idea of having strict dichotomies as presented in the general premises and spontaneously suggested that the target category could include both attributes (e.g., Both girls could have a mix of striped and dotted balls/The color of the hat does not determine whether someone will work for the bad or good people). This raises questions about the extent to which these general premises were considered as propositions conveying explanations, regularities, or hypotheses about the world. The general premises used in the current experiments conveyed information about an identifying property as a rule to define the target category (e.g., "All of Chloe's balls

are striped/All knights of King William wear a white hat"). However, these properties pertain to the non-essential and accidental features of the category (e.g., colour of the hats/balls). It is possible that one critical feature that makes general beliefs privileged and relatively resistant to change in the face of new evidence is the type of information they convey. Research has shown that children do not consider all properties that are true generalizations of the target categories as law-like features of these categories (Haward et al., 2018; Prasada & Dillingham, 2006; 2009; Prasada et al., 2013). Instead, children understand that some properties (e.g., the property of barking for the kind dog), relate to the target kind/category in a way that defines it while other properties (e.g., the property of wearing collar for the kind dog) are more about how often they are observed among individual members of the category. In this respect, it is arguable that individuals might prioritize their existing beliefs about the general rules over individual observations only when these rules convey information about the essential properties of target categories. Chapter 3 examines the relative strength of generalizations about essential and non-essential (accidental) properties of a target category to inform children's belief-revision.

Chapter 3
Children's revision of category-based inferences in the face of inconsistent evidence

3.1 Introduction

Children who continuously encounter novel entities and learn information about them face two main challenges. The first challenge concerns how to make sense of and organize this information. The ability to make inferences and reason inductively about categories provides them with an efficient and adaptive tool that they could rely on in this process. In other words, children could treat new information differently depending on whether the information conveys generalizable, category like information or not. For example, if information is conveyed in a generic form (e.g., dogs are 4-legged) then children will take it as representative of the whole category rather than representative of an individual category member only (Gelman & Roberts, 2017; Lawler, 1973; Leslie, 2007, 2008; Prasada, 2000). A second challenge emerges when they face new information which creates inconsistency within their existing knowledge set. When this inconsistency calls for revision of beliefs which were previously considered to be true, the question is whether all types of information about novel entities weigh the same when informing our inferences about categories. Or would it be beneficial to prioritize certain type of information in our category-based reasoning? For example, we might initially hold the following beliefs about doctors: "Doctors are qualified in medicine" and "Doctors wear white coat". When we encounter someone who is qualified in medicine and wears a black coat, it is more likely that we question our existing belief about their coat color than their educational qualification as the latter belief conveys an essential feature of the category, doctors. The main goal of the current study is to examine whether 4- to 7-year-old children prioritize law-like information over accidental information when revising their prior beliefs about novel natural kind categories.

Starting from the second year of life, children rely on perceptual similarity as well as knowledge-enriched theories to build up their category-based representations (see Gelman & Meyer, 2010 for a review). The perceptual features of an animal or artifact (e.g., shape, color etc.) are undoubtedly salient cues for children to make inferences about category membership (e.g., Quinn & Eimas, 1996). Some researchers also argue that labels (e.g., See this bird!) are similarly salient perceptual features that facilitate children's inductive inferences (Sloutsky, Fisher, & Kloos, 2015). On the other hand, proponents of a composite view regarding the contribution of

perceptual as well as conceptual similarities in shaping children's categorization, propose that children rely on these low-level perceptual features because they denote an underlying deeper structure for the category (Gelman & Meyer, 2010). According to this view, which is termed as psychological essentialism, children and adults believe that certain categories have some deep hidden quality determined by nonobvious features that is to some extent reflected in terms of the obvious features and perceptual similarities (Gelman, 2003). Supporting evidence for psychological essentialism comes from studies which have shown that preschool age children consider unobservable/nonobvious shared properties (e.g., having hollow bones) as affording higher inductive power than the shared observable/obvious properties (e.g., having same shape trunk) (Keil, Smith, Simons, & Levin, 1998; Lawson, Fisher, & Rakison, 2015).

The essentialist view characterizes categories as having sharp boundaries, immutable and unchanging. However, there is now accumulating evidence revealing that children do not assume that all category-based beliefs (e.g., "duck lay eggs" and "boys like blue") reflect essences to the same extent (Foster-Hanson, Roberts, Gelman & Rhodes, 2018; Noyes & Keil, 2019; 2020). When 4- to 9-year-old children hear a category generalization such as "Hibbies eat this kind of berry", they expect members of the category to display the normative feature regardless of whether the category denotes a social kind or natural kind (Foster-Hanson et al., 2018). However, their expectation for category heterogeneity was greater for the social kind compared to a natural kind; while one instance was sufficient to shape their normative expectations for the natural kind, they needed more direct evidence for the social kind. Another recent study showed that starting around 6 years of age, children understand that different causal mechanisms underlie natural and social kinds (Noyes & Keil, 2020). While 4 and 5-year-old children indiscriminately assumed socialization/culture as the driving force for both, children 6 years and up understood that natural kinds are biologically determined, and social kinds are culturally determined. Therefore, rather than assuming that generic statements convey information about the essence of the respective kind, children presumably take into account how the property conveyed through the generic statement relates to the category. In fact, prior research shows that children differentiate between different types of kind-related information to inform their inductive generalizations (Fisher, Godwin, & Matlen, 2015; Foster-Hanson et al., 2018; Prasada & Dillingham, 2006; 2009; Prasada et al., 2013; Sloutsky et al., 2015). Preschool age children appreciate that some properties of a given kind (e.g., "Cats meow") are essential in the sense that

they exist in the individual members of the kind by virtue of their being while others may exist in a substantive majority of the members of the kind (e.g., “Cats scratch furniture”) but bear no essential relation to the kind and are accidental. For example, 4- to 7-year-old children have normative expectations for properties such as, “Dogs bark” but not for properties such as, “Dogs wear collars”, the latter being statistically prevalent but not category essential (Haward et al., 2018). Thus, children understand that there is something beyond how often certain properties are observed among the individual members of the category, making a distinction between essential and non-essential properties of the kind categories.

The existing research provides evidence for the variability and flexibility in the way children form category-based beliefs about the world. However, we do not know to what extent this flexibility and variability would be reflected in the revision process of their beliefs when children encounter new evidence that is incompatible with their existing category representations. In light of the findings by Noyes and Keil (2020) reviewed above, one can argue that children’s general beliefs about natural kinds which are represented through biologically determined relations would be prioritized and show resistance to revision while general beliefs for social kinds would be revised more flexibly as they convey socially/culturally determined information about the category. The studies reported in Chapter 2 partially support this argument, showing that the beliefs which conveyed information about the properties characterizing a social category (e.g., “All of Chloe’s balls are striped/All knights of King William wear a white hat”) were not prioritized in children’s and adults’ knowledge set. Both children and adults flexibly revised these beliefs in light of new evidence. There is indeed another aspect of the category beliefs tested in Chapter 2 which might have rendered them prone to revision. Although these beliefs were true generalizations of the target categories, they conveyed information about the accidental and non-essential properties of the category. Given the evidence that the type of relation between properties and their respective categories informs children’s inductive generalizations and normative expectations (Haward et al., 2018; Prasada & Dillingham, 2006; 2009; Prasada et al., 2013), it is possible that the general beliefs in Chapter 2 were not prioritized due to the type of information they conveyed. Arguably, information which conveys underlying law-like features of the physical and social world would have a higher status in people’s belief set compared to information which conveys more accidental features of the world and hence would show greater resistance to revision (Revlin et al., 2005). Relatedly, category-based generalizations would be

prioritized to the extent that they convey information which bears a principled connection to the kind.

The current study aims to test these predictions by examining whether children can use the ability to differentiate between essential and non-essential properties of a natural kind category to inform their decisions in belief-revision. Do children prioritize essential properties over non-essential properties when revising their prior beliefs about novel natural kind categories in the face of inconsistent evidence? In other words, are beliefs that convey information about an essential property of the target category more resistant to revision compared to beliefs that convey non-essential property of the category?

A modified version of the paradigm used in Foster-Hanson et al. (2018) was utilized to explore the differential weight children attribute to essential vs non-essential properties of a natural kind category during belief-revision. Children learned about some novel categories (e.g., Morseths and Scoobits) and some properties of these categories. For each category, two pieces of information were presented about the target category: an essential property (e.g., "Morseths have two bones inside their bodies") and a non-essential property (e.g., "Morseths wear purple glasses on their eyes"). The research question tested in the current study concerned which of their existing beliefs, beliefs about the essential or the non-essential property of the category, children would readily give up on when they encountered a new exemplar carrying a property that is inconsistent at the non-essential level (e.g., with two bones inside the body and yellow glasses on the eyes) or at the essential level (e.g., with three bones inside the body and purple glasses on the eyes).

The current study aimed to show that 4- to 7-year-old children's beliefs about the law-like nature of the world is more resistant to revision compared to more arbitrary, accidental beliefs. In this regard, it was predicted that children's tendency to reason on the basis of their general beliefs would depend on the type of relation between the target property and the kind; in the face of conflict, essential properties would be favored over non-essential properties in revision of their category judgements. Specifically, children would prefer to retain their initial categorization based on the essential property of the category even in the presence of an exemplar with incompatible non-essential property. On the other hand, when they encounter evidence for the essential properties inconsistent with their initial categorization based on the non-essential

property, children would prefer to revise their initial categorization. In light of previous findings showing no age-related differences among 4- to 7-year-old children in the way they treated essential vs non-essential properties (see Haward et al., 2018), the current study did not test any specific hypothesis in relation to age.

3.2 Method

3.2.1 Participants

A total of 110[1] 4- to 7-year-old children (58 F, M_{age} = 68.3 months, SD = 11.3, Range 48.5 - 87.3) participated in the study. An additional 15 children were excluded due to possible developmental delays/behavioral problems (n = 5), inattentiveness (n = 4), no clear response to the test questions (n = 3), experimenter error (n = 1), being a non-native speaker of Turkish (n = 1), failure on control questions across all trials (n = 1). Children were noted as inattentive if they did not pay attention to the stimuli and/or did not follow the storyline (e.g., looking around or engaging in irrelevant conversation with the experimenter). Development delay/behavioral problems were determined based on consultation with the daycare/school counselor or the parental report on the demographic information form (See Appendix A). Four and 5-year-old children were recruited at private preschools/daycares and 6- and 7-year-old children were recruited at private elementary schools in Turkey. The sample was composed of typically developing children whose native language was Turkish. Children came from families with middle to high socio-economic background. Parents gave their written consent for their children's participation before the study began. Children received a sticker for their participation.

3.2.2 Materials and Design

Inspired by the stimuli used in Foster-Hanson et al. (2018), a story about a new planet and different kinds of creatures living on this planet was developed. The story introduced children to a pair of exemplars that belong to two novel biological categories (e.g., Morseths and Scoobits) and provided information about the properties of these novel categories. For each pair of

[1] Based on prior research (e.g., Haward et al., 2018), the target sample size was determined as 120. However, due to occurrence of 2020 Coronavirus Pandemic, data collection was terminated.

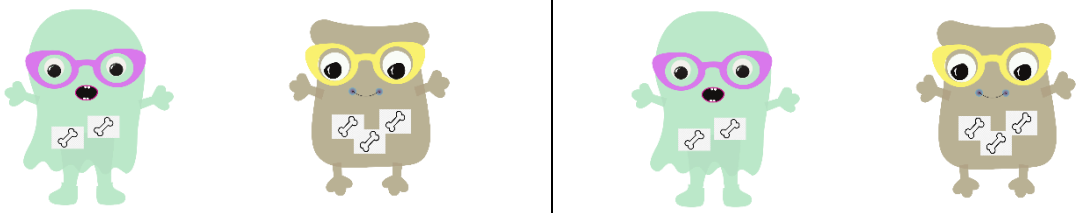
exemplars, children were presented two pieces of information, one conveying an essential property of the novel category (e.g., having two vs. three bones inside their body) and one conveying a non-essential/accidental property of the novel category (e.g., wearing purple vs. yellow glasses). Next, children were asked to categorize a new creature exemplar based on the evidence available to them sequentially. In order to avoid any perceptual bias in categorization and maximize children's ability to make category-consistent inferences, the new exemplar was not visually available to children but instead children were shown a door and were told that there was a new creature behind the door (Fisher et al., 2015). Children received two pieces of evidence about the new exemplar one by one and were asked to categorize the new exemplar upon each piece of evidence.

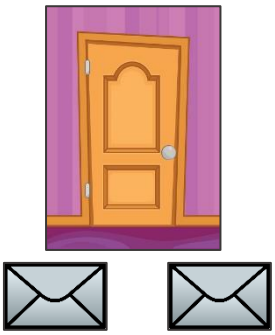
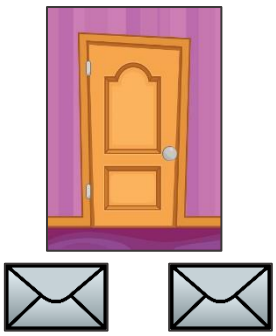
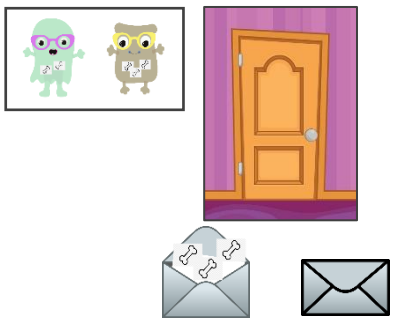
The study manipulated the type of property which was presented as the first evidence for initial categorization and which was presented as the second evidence inconsistent with the first one. Table 3.1 depicts an overview of the general structure of the storyline for the experimental conditions. In the Essential Condition, the first evidence children received was about the essential property of the exemplar (e.g., having two bones inside its body). In the Non-essential Condition, the first evidence children received was about the non-essential property of the exemplar (e.g., wearing purple glasses). Upon the presentation of the first evidence, the initial categorization phase was introduced to ensure that children learned the association between the properties and their respective categories. Children were asked to infer the other property of the target category based on their existing beliefs about the properties of the two categories and the first piece of evidence available to them. Children's response at this phase was coded as their initial categorization of the new exemplar. To aid children's representation of these properties and decrease the working memory load of the task, the researcher presented a picture depicting the two novel categories with their relevant properties. Following their initial categorization, children received the second piece of evidence. Critically, in both conditions, the second piece of evidence was inconsistent with their initial categorization, e.g., wearing yellow glasses in the Essential Condition and having three bones in the Non-essential Condition. Upon the presentation of the second piece of evidence, the test phase began. Children were asked to categorize the new exemplar based on the two pieces of evidence available to them. Given that the two pieces of evidence were incompatible with one another, children's response was coded in

terms of whether they revised their initial categorization of the exemplar considering the second piece of evidence.

In the experimental conditions, the two pieces of evidence conveying essential and non-essential property of the novel exemplar were presented successively. This feature of the task raised the possibility that participants considered the order of presentation (first vs second piece of evidence) as a more reliable cue than the information type (essential vs non-essential property) which could result in two potential outcomes: 1) participants who believed in what they heard first about the exemplar would retain their initial categorization regardless, 2) participants who believed in what they heard last about the exemplar would revise their initial categorization regardless of the condition. In order to tease apart the effects of condition from the potential effects of sequential presentation of the evidence, we ran a Control Condition in which participants were presented with the two pieces of evidence - conveying a non-essential and an essential property of the novel exemplar respectively - simultaneously and asked to categorize it. Similar to the experimental conditions, these two pieces of evidence were inconsistent with one another (e.g., wearing purple glasses and having three bones) such that the one of them conveyed information about a non-essential property matching with one category while the other one conveyed information about an essential property matching the other category (See Appendix D for an example trial in the Control Condition).

Table 3.1 Overview of the storyline structure for the experimental conditions.

	Essential Condition	Non-essential Condition
Introduction of the two target kind categories	 Morseths and Scoobits, two different creatures. Morseths and Scoobits are very different from one another.	Morseths and Scoobits, two different creatures. Morseths and Scoobits are very different from one another.

	This is a Morseth. Morseths have two bones inside their body. See? Here are two bones inside its body. And Morseths wear purple glasses on their eyes. See? And this is a Scoobit. Scoobits have three bones inside their body. See? And Scoobits wear yellow glasses on their eyes. See?	This is a Morseth. Morseths have two bones inside their body. See? Here are two bones inside its body. And Morseths wear purple glasses on their eyes. See? And this is a Scoobit. Scoobits have three bones inside their body. See? And Scoobits wear yellow glasses on their eyes. See?
Introduction of the new exemplar	 Now, there is a new creature behind this door. Max does not know whether this creature is a Morseth or a Scoobit. We will help him find out. There are cues in these envelopes. Let's open one of them.	 Now, there is a new creature behind this door. Max does not know whether this creature is a Morseth or a Scoobit. We will help him find out. There are cues in these envelopes. Let's open one of them.
Initial categorization of the new exemplar	 Look, the first cue we have is three bones. So, the creature behind the door has three bones inside its body. Then, what color glasses do you think it wears?	 Look, the first cue we have is purple glasses. So, the creature behind the door wears purple glasses on its eyes. Then, how many bones do you think it has?

Revision	 And the other cue we have is purple glasses. So, the creature behind the door has three bones inside its body and wears purple glasses on its eyes. What do you think it is? A Morseth or a Scoobit?	 And the other cue we have is three bones. So, the creature behind the door has three bones inside its body and wears purple glasses on its eyes. What do you think it is? A Morseth or a Scoobit?

3.2.3 Procedure

The study used a between-subjects design; with each participant being randomly assigned to one of three conditions: essential (n = 40), non-essential (n = 36) and control (n = 34). The procedure was the same for all conditions. Participants were tested individually in a quiet room at their schools. One participant was tested at home. The stimuli were presented on a computer and the story line was narrated live by the researcher.

The pilot data for an earlier version of the procedure showed that children learned the structure of the task across trials and responded accordingly. In order to avoid any potential learning effects, each session included a practice trial, 2 test trials and a filler trial in between. In the practice and the filler trials, the same stimuli and storyline were used except that the second piece of evidence was consistent with the first piece of evidence (i.e., with participants' initial categorization).

Four stories were created two of which were used in the test trials. The other two were used in the practice and filler trials. For half of the children, test trials consisted of stories in which the essential properties of the target categories differed quantitatively (e.g., having two vs three

bones) while for the other half, they consisted of stories in which the essential properties differed qualitatively (e.g., having a small vs big brain) (See Appendix E for the complete list of stories). During the encoding phase where the two kind categories were introduced to the participants, the first property introduced about the category was counterbalanced across participants. Half of the participants first received information about the essential property of the target category (e.g., "Morseths have two bones inside their bodies") and the other half first received information about the non-essential property category (e.g., "Morseths wear purple glasses on their eyes"). In addition, the side at which the target category appeared on screen was counterbalanced across trials for each participant.

3.2.4 Coding and Reliability

As described above the experimental conditions involved two phases. In the initial categorization phase, participants were asked to categorize the new exemplar based on the first piece of evidence they were given. The purpose of this phase was to control for children's ability to make inferences about the category membership of the novel exemplar based on the information they were provided about the categories. Participants' responses to the initial categorization question in each trial were coded as 'true' (1) and 'false' (0). Data for trials in which children failed to make a correct inference at this phase were excluded from the analyses (n = 5). The test phase targeted whether they revised their initial categorization based on the second piece of evidence they were given. Participants' responses in the test phase were coded as 'revised' (1) and 'not revised' (0) for each trial.

In the control condition, participants' response to the categorization question in each trial was coded as 'categorization based on essential property' (1) and 'categorization based on non-essential property' (0).

Participant responses were live scored during testing. Sessions were also video recorded for reliability purposes. A trained research assistant coded 65% of the included participants. The research assistant was blind to the study hypothesis and the conditions. The interrater reliability was high for both trials across all conditions, Cohen's κ ranged from 0.88 (p <.0.0001) to 1.000. Disagreements were resolved through discussion.

3.3 Results

Preliminary analyses were conducted to ensure similar distributions of age and gender across conditions and possible effects of order on children's tendency to categorize novel exemplars on the basis of essential vs non-essential properties. A univariate ANOVA test showed that the mean age of children across conditions did not significantly differ from one another, $p = .84$ ($M_{essential} = 69.2$ months, $M_{non\text{-}essential} = 68.0$ months, $M_{control} = 67.5$ months). The gender distributions across the conditions were also similar, X^2 (2, N = 110) = .001, $p = .999$. Moreover, story type (quantitative vs qualitative difference between the essential properties of the target categories) did not affect children's overall tendency to base their categorization on an essential vs. non-essential property of the exemplar, X^2 (6, N = 100) = 8.25, $p = .22$.

The main goal of the study was to examine the effects of information type (essential vs non-essential) on belief-revision. Thus, the influence of the type of information presented by new evidence on children's tendency to revise their initial categorization was tested. It was predicted that children would be more likely to revise in the non-essential condition compared to the essential condition. In order to accommodate the binary nature of the dependent variable (0 vs 1) and the presence of a within-subjects factor in the data (trial), a Generalized Estimation Equation (GEE) with binomial distributions, logit-log link functions and independent covariance structures was used. The dependent variable was participants' revision in the test question (revised vs not revised) in any given trial. The predictors were information type (essential vs non-essential), age (in months), and trial (first vs second).

As discussed earlier, there was no specific predictions regarding age-related differences given prior findings. However, age was included as an exploratory factor in the model. Moreover, in order to explore whether there was a change in individual participants' response pattern across trials, trial was also included in the model as an exploratory factor.

There was no significant main effect for information type, Wald X^2 (1) = .081, $p = .76$, age, Wald X^2 (1) = .487, $p = .49$, or trial, Wald X^2 (1) = 1.687, $p = .194$. The findings suggested that: 1) children were equally likely to revise initial categorization when the second piece of evidence was essential vs non-essential, 2) there were no age-related changes in children's revision tendency, 3) children did not shift their revision strategies across trials. The results did not change when only information type was included in the model, Wald X^2 (1) = 1.469, $p = .23$.

Despite the lack of a main effect for age, children's likelihood to revise their initial categorization was broken down by age groups across conditions to check any observable pattern at the descriptive level. As seen in Figure 3.1., 5-year-old children are more likely to respond in the expected direction than the other age groups: 1) a relatively higher percentage of 5-year-olds retain their initial beliefs across both trials in the Essential Condition, 2) a relatively higher percentage of them revise their initial beliefs across both trials in the Non-essential Condition. While 3-4-year-old children were almost evenly split across three response patterns in both conditions, 6-year-old children tended to switch their reasoning across trials regardless of the condition. However, due to the small number of children in each age group, it is possible that the observed differences in children's response pattern across age groups were not reflected in the omnibus analysis.

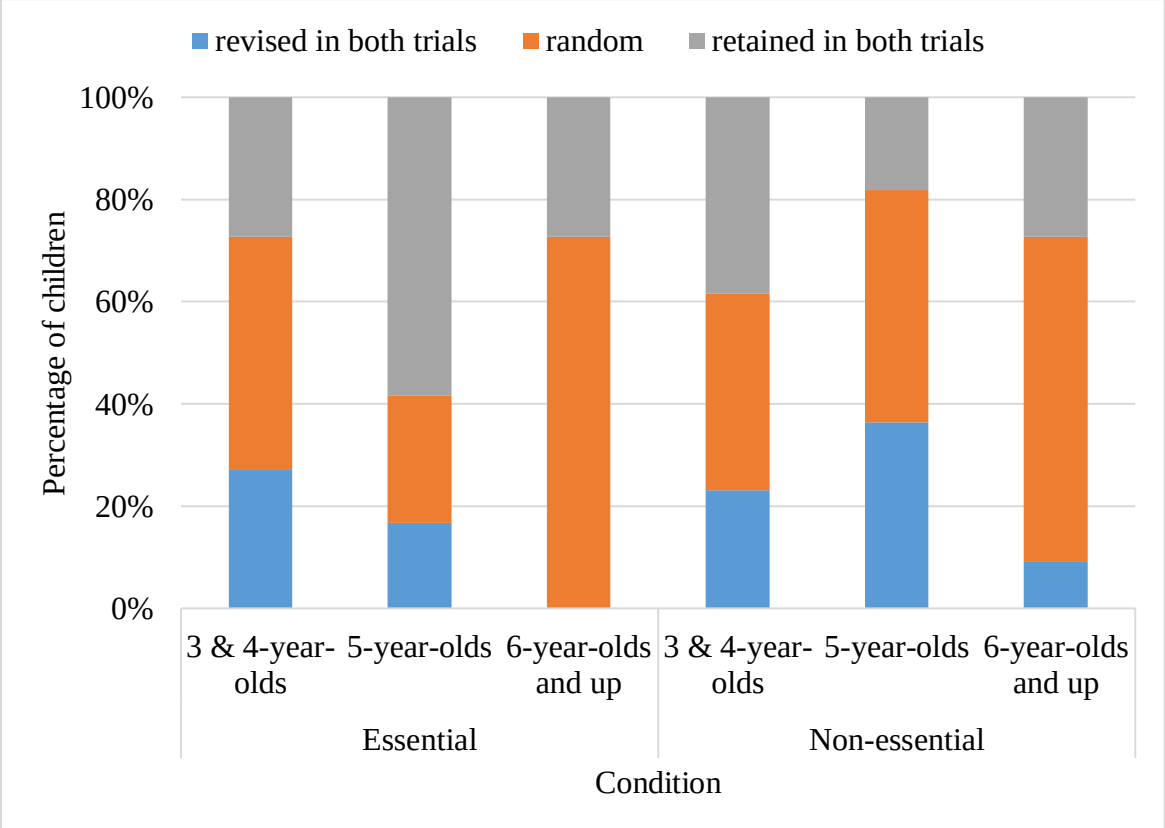


Figure 3.1. Children's response pattern across two trials as a function of age and condition.

Next, participants' likelihood of revising their initial categorization in a given condition was tested against chance. Two separate chi-square goodness-of-fit tests were run to compare the distribution of participants' responses across two trials against chance. Participants' revision

tendency across two trials did not significantly differ from chance in the Essential Condition, X^2 (2) = 3.882, p = .14 or in the Non-essential Condition, X^2 (2) = .257, p = .88. (See Figure 3.2). Given the possibility that children might have changed their revision strategies from the first to the second trial, separate follow-up binomial tests were run to check revision tendency in each trial against chance. In the Essential Condition, 25 out of 37 (68%) participants retained their initial categorization on the first trial, which was significantly above chance, p = .047. In the second trial, 21 out of 37 (57%) participants retained their initial categorization, p = .51. In the Non-essential Condition, only 14 out of 35 participants revised (40%) their initial categorization in the first trial (p = .31), and 20 out of 36 (56%) revised their initial categorization in the second trial (p = .62).

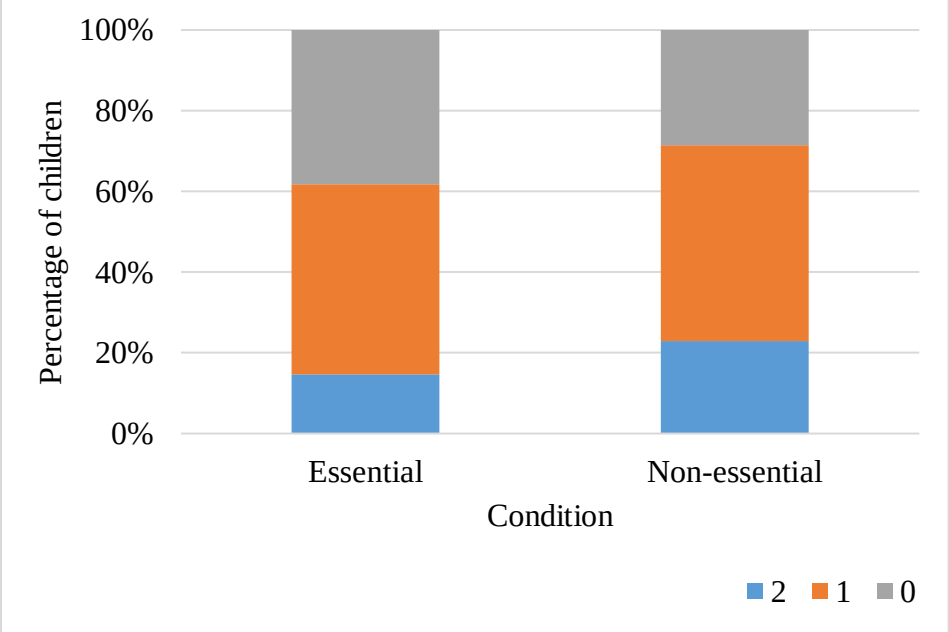


Figure 3.2. Children's response pattern across two trials as a function of condition.

Finally, to ensure that the findings in the experimental conditions were not due to the successive presentation of the information, participants' responses in the control condition were analyzed to examine the tendency to favor essential information over non-essential information when making inductive inferences. It was predicted that children would categorize the new exemplar based on the essential property significantly more often than chance. First, participants' response tendency across two trials was examined. A chi-square goodness-of-fit test was run with the expected values of .25, .50 .25 respectively to compare the distribution of participants across different

response patterns. Participants' tendency to rely on essential information in inductive inference across two trials differed significantly from chance, X^2 (2) = 15.258, $p < .01$. Separate binomial tests for each trial showed that, 25 out of 34 participants (74%) favored the essential property over the non-essential in the first trial ($p < .01$) and 22 out of 31 of them (71%) did so in the second trial ($p < .05$).

3.4 Discussion

The current study examined whether 4- to 7-year-old children prioritize certain types of beliefs in their category representation when a new evidence inconsistent with prior knowledge calls for belief-revision. Specifically, the study tested whether children take into account the type of relation a piece of information has to the target kind category when they are required to revise their prior beliefs. Prior research found that children's category-based beliefs at this age show variability and flexibility depending on the type of information conveyed about the category (Noyes & Keil, 2019; 2020; Haward et al., 2018). Therefore, it was predicted that beliefs about essential information of the category would be favored over beliefs about non-essential information in children's category-based inferences in the face of inconsistency. As a result, prior beliefs based on generalizations about essential properties of a kind category would be more resistant to revision than prior beliefs based on generalizations about non-essential/accidental properties.

The findings revealed that children were flexible in revising their existing beliefs regardless of the type of information they entailed. In the current paradigm, children's initial beliefs were formed based on one type of information, e.g., a piece of evidence about an essential property of the new exemplar, which subsequently turned out to be incompatible with new information they received, e.g., a second piece of evidence about a non-essential property of the new exemplar. Children's tendency to revise their beliefs about the category membership of a new exemplar was not affected by whether the new evidence mismatched the category in terms of its essential property or its non-essential property. In both cases, around half of the children's decision about revising their old beliefs were random; they revised in one trial but retained in the other trial. Despite the lack of a clear preference for essential information over non-essential information in the overall performance, when children's reasoning strategies were examined on the basis of individual trials, it was found that the majority of them (68%), a proportion significantly higher

than would be expected by chance, resisted revising their existing beliefs based on essential information in the first trial. While this finding partially supports the prediction regarding the relative status of essential beliefs over non-essential beliefs, children's overall flexibility in revising their beliefs regardless of the information type needs explanation.

A possible explanation could be that both types of information were conveyed using generic language. Prior research has attributed generics a privileged status in children's category representation due to their power to license generalizations of properties across individual members of a kind category (Cimpian, 2016; Graham et al., 2016). In the current study, both types of information (essential and non-essential) were conveyed using generic language which might have led children to represent these properties as equally signifying features of the kind category. In addition, research shows that preschool children understand that there might be exceptions to the shared properties of natural kinds and hence accept that some of the category members can exhibit incompatible properties (Brandone & Gelman, 2009; Hollander, Gelman, & Star, 2002; Brandone et al., 2015). For example, they judge a generic statement such as "Crullets have spots" as true, even though the target property was present in only 66% of the category members. In this respect, one can argue that children would consider their initial beliefs indispensable regardless of whether they were based on essential or non-essential information. In other words, they would be as likely to accept incompatibility in terms of the non-essential property (e.g., what they initially categorized as a Scoobit to wear purple glasses on its eye) as essential property (e.g., what they initially categorized as a Morseth to have three bones inside its body). However, this explanation is unlikely because then we would see a robust resistance to revision of prior beliefs regardless of whether these beliefs were based essential or non-essential information about the category which was not the case. Instead, the current findings showed that children's overall tendency in both conditions was to revise in one trial but retain in the other trial.

This raises the possibility that both types of beliefs were equally strong in shaping children's representation of the categories. However, this is an unlikely explanation because although children's reasoning about which prior beliefs to revise was not influenced by whether the property was essential or non-essential, the type of information seemed to affect their category inferences. When two types of information about a novel exemplar, essential and non-essential, were pitted against one another simultaneously as in the control condition, children reliably used

the essential information to infer the category membership of the exemplar. Overall, around half of the children (55%) consistently categorized the new exemplar on the basis of its essential property while only a small proportion of children (10%) consistently categorized it based on its non-essential property, and around one-third of the children (35%) chose between the two pieces of information randomly. Furthermore, on the basis of individual trials, the majority of children favored/relied on information about the essential property to inform their category representation of the exemplar (74% in the first trial and 71% in the second trial).

Considering the discrepancy in children's reasoning during belief-revision and category inferences, it is possible to argue that the differentiation among beliefs conveying various types of information is still developing through preschool years and thus not strong enough to inform children's reasoning during belief-revision process. Findings from a recent study which examined the differential status of various properties in children's representation of kind categories among 4- to 9-year-old children support this explanation. It has been shown that starting at the age of 6, children did not consider all properties which were conveyed using generics as related to the essence of the kind but differentiated between biological (e.g., "Vawnsies feel sick when they drink milk") and cultural properties (e.g., "Vawnsies believe that fish talk to God") in terms of whether they were due to the category essence or socialization (Noyes & Keil, 2020). However, 4-5-year-olds were more likely to believe that both types of properties were a result of socialization, suggesting that the ability to recognize what causal structures underlies the relation between properties and kind categories is still developing between the ages of 4- to 6-years. In this respect, the discrepancy in the way children reasoned when the two types of information were presented sequentially versus simultaneously suggests that children's sensitivity to the relative status of essential versus non-essential information in determining the novel exemplar's kind category might be overridden by their confusion due to the successive presentation of conflicting evidence. Recent research showed that 4- and 5-year-old children changed their responses about which cup they thought the sticker was hidden under when simply asked a neutral follow-up question (Bonawitz, Shafto, Yu, Bridgers, & Gonzalez, 2020). Given the ambiguity inherent in the paradigm (the new exemplar was never visually present and children received no feedback on their guesses), the presentation of the conflicting evidence upon their initial category inferences might have led children to simply switch their reasoning about the new exemplar. The current study cannot speak to potential individual

differences in children's evaluation of evidence as a function of its presentation order and potential age differences in how children reason when revising their beliefs in the face of inconsistent evidence. These are open questions for future research.

Chapter 4
General Discussion

A great deal of developmental research has examined children's proclivity to revise their prior beliefs. The primary focus of these investigations has been whether and under what conditions, children endorse new information which defies their existing perceptual or intuitive knowledge (e.g., whether they accept an ambiguous animal as a dog despite initially believing that it is a cat). Since earlier studies did not portray children's knowledge of a particular entity as composing of a set of interrelated beliefs, they could not address questions about which of their prior beliefs children revise in order to resolve the inconsistency that the new evidence leads to in their belief set.

Do individuals have a preference for which existing beliefs they revise? Are some beliefs privileged and relatively resistant to change in the face of inconsistent new information? Critical to this question is an understanding that our representation of a particular entity consists of several beliefs with different levels of entrenchment. Some of these beliefs are highly entrenched, as they pertain to the law-like aspects of the world, whereas others pertain to relatively more transient and superficial aspects and hence are less entrenched than the former. In this respect, when new evidence introduces an inconsistency in our existing belief set about an entity, it is expected that the beliefs based on law-like generalizations would be more resistant to revision compared to beliefs about superficial features of the entity. The goal of the present work was to examine which beliefs are prioritized in children's (and adults') knowledge revision when having to resolve an inconsistency caused by new evidence.

4.1 Synthesis of findings

To address how children reconcile new evidence in their existing belief set, children's belief-revision was examined using adaptations of the belief-contravening paradigm which is widely used in adult research. In the belief-contravening paradigm, children's knowledge about a particular entity is represented in terms of a set of believed propositions and inferences drawn based on these propositions, which enables an examination of whether any of these previously held beliefs are favored over others in case one encounters inconsistent evidence.

Chapter 2 asked whether children are more likely to revise beliefs based on observations and retain beliefs based on generalizations about a particular entity when faced with inconsistent evidence. Study 1 was conducted as a follow-up on earlier work by Van Hoeck and colleagues (2012), who found that 7-year-old children, like adults, showed a robust tendency to revise prior beliefs which are based on individual observations (i.e., particular premises) and retain those based on generalizations (i.e., general premises) to resolve the inconsistency that new evidence brings to an existing belief set. A modified version of the original paradigm was developed to test when in development children begin adopting the reasoning strategies deployed by older children and adults. With the help of visual aids, 5- and 7-year-old children and adults first learned about some distinct attributes of two categories, e.g., the pattern of balls that belong to two characters: "All of Sophia's balls are dotted. All of Chloe's balls are striped". Next, they were presented with observational evidence, e.g., that one of the characters takes a ball from her box and brings it to the table: "Chloe brings a ball from her box to the table". After participants made an inference about the outcome event, e.g., the pattern of the ball on the table, based on what they initially learned (e.g., the ball on the table is striped), new evidence incompatible with their prior reasoning (e.g., "Let's assume that the ball on the table is dotted") was introduced. When prompted to resolve the inconsistency in their belief set, both 5- and 7-year-olds and adults were equally likely to choose between revising beliefs about the category generalization (e.g., "Chloe has dotted balls as well") and revising beliefs about the particular observation (e.g., "It is Sophia who brings a ball to the table").

To establish whether the discrepant findings with prior research were due to the modifications in the original paradigm, a replication study was run with only adults using exactly the same stimuli as Van Hoeck and colleagues. Study 2 failed to replicate earlier findings; adults chose randomly between revision of the category generalization (e.g., "The knights of King William can also wear a black hat from now on") and that of a particular observation (e.g., "This knight here works for King Igor"). In contrast to children and adults in Study 1 (the modified version), adults' reasoning strategies in Study 2 (the original paradigm) showed high consistency across trials. While almost half of them (45%) revised the general premise, the remaining majority (41%) revised the particular premise in both trials, regardless of the inference type.

These studies together did not support earlier findings regarding children's and adults' preference for the generalist solution to reinstate consistency in their belief set. Instead, both

children and adults consider the revision of each belief equally plausible, suggesting that they do not privilege one type of belief over the other.

A possible explanation for the lack of preference among existing beliefs observed in Chapter 2 could be that the type of information conveyed through the category generalization in these studies pertained to the superficial aspects of the world (e.g., the pattern on the balls that belong to two characters/the hat color of knights who work for different kings). Therefore, these beliefs were not resistant to revision as would be expected. It is possible that beliefs conveying law-like information about how the physical and social world work should have a privileged status in individuals' knowledge set and any tendency towards adopting a generalist solution in belief revision would be more pronounced in situations where the generalizations about the target category convey essential, non-accidental aspects of the category rather than non-essential, accidental aspects.

Chapter 3 addressed this possibility by examining the relative strength of essential and non-essential properties in driving 4- to 7-year-old children's inferences about a target category membership. Children were presented with two kind categories and their properties: for each kind, they received one piece of information about its essential property (e.g., having two bones inside its body) and one piece of information about its non-essential property (e.g., wearing purple glasses on its eyes). Next, children were told about a novel creature (invisible to children throughout testing) whose category membership they were required to infer based on the two pieces of evidence they were given sequentially. One piece of evidence was about the novel exemplar's essential property (e.g., the number of bones it has inside its body) while the other piece of evidence was about the novel exemplar's non-essential property (e.g., the color of the glasses it wears on its eyes). Critically, these two pieces of evidence conveyed inconsistent information about the novel exemplar's category membership. It was predicted that children would prioritize beliefs about essential properties in their reasoning about the kind categories over beliefs about non-essential properties during the process of belief-revision. Following this line of thought, when new evidence calls for revision of existing beliefs, children should prefer to retain their essential beliefs about the category and revise their non-essential beliefs about it.

The findings partially supported these predictions. The pattern of responses across trials was inconsistent. However, an examination of children's reasoning in the first trial revealed

suggestive evidence for the relatively privileged status of beliefs based on essential information over those based on non-essential information. Sixty-eight percent of children resisted revising their initial beliefs about the novel exemplar's kind when their initial categorization was driven by the evidence about its essential property. Moreover, a control condition showed that when children received the two pieces of information simultaneously rather than sequentially, their beliefs about the essential property of the exemplar was more likely to inform inferences about category membership.

Taken together, these studies suggest that when incorporating new information into existing knowledge, adults, and children between the ages of 4 to 7 years do not have a strong preference for which of their existing beliefs to revise. Overall, 4- to 7-year-old children as well as adults in the current study revised both their general/essential beliefs and their particular/non-essential beliefs about categories. A slight tendency to prioritize beliefs about essential information appeared in some circumstances: 1) they did not revise their initial beliefs based on the essential property of the novel exemplar when they encountered inconsistent evidence for the first time and 2) in situations which did not call for belief-revision; they favored essential beliefs to inform their category inferences when these were pitted against non-essential beliefs simultaneously.

4.2 Contributions and directions for future research

This section starts with a discussion of the main contributions arising from the use of the belief-contravening paradigm in understanding children's reasoning during the belief-revision process. Next, it turns to contributions and possible future directions regarding the findings on the relative status of various belief types in children's representation of the world.

4.3 Preschool age children can and are motivated to reinstate consistency in their belief set

The current work has demonstrated that the belief-contravening paradigm, with age-appropriate content and simplicity, can be used with preschool age children to reveal the reasoning process they engage in when revising their prior beliefs. First of all, the present studies provided further evidence of 4- to 7-year-old children's ability to deduce valid conclusions based on category premises, which is a prerequisite for belief-contravening problems. The belief-contravening problems are typically presented in the form of conditional, "If-then", statements (e.g., Rescher,

2007; Elio & Pelletier, 1997; Bryne & Walsh, 2002). In Chapter 2, the premises were couched in a category form, "All of Sophia's ball are dotted. All of Chloe's balls are striped." using universal quantifiers, and in Chapter 3 they were couched in the generic form, "Morseths have two bones inside their body. Scoobits have three bones inside their body." In terms of the underlying reasoning process, both forms of premises are considered isomorphic to a conditional form; "If a ball belongs to Sophia, it is dotted" and "If it has two bones, it is a Morseth" respectively (See Markovits, Venet, Janveau-Brennan, Malfait, Pion, & Vadeboncoeur, 1996). In fact, an earlier study investigating how these two formulations affected children's performance did not find any differential performance (Roberge & Paulus, 1971). In Chapter 2, 5- and 7-year-old children were able to draw valid conclusions in both Modus Ponens inferences (e.g., whether a ball Chloe brought from her box to the table would be dotted or striped) and Modus Tollens inference (e.g., whether Chloe or Sophia could have brought the dotted ball to the table) using premises about two arbitrary categories (e.g., Chloe's and Sophia's balls) which was evident by the high rate of correct responses given to the inference question. In Chapter 3, 4- to 7-year-old children were able to infer the second property of a novel creature (e.g., the color of its glasses) based on the first piece of evidence (e.g., the number of its bones) and generic information they had about two kind categories, again evident by the high rate of correct responses given in the initial categorization phase. Therefore, the current work provides corroborating evidence that an elementary form of deductive reasoning ability, analogous to conditional reasoning, is in place as early as 4 years of age.

The experimental tasks used in the current work required that children understand when new evidence is incompatible with their prior knowledge. Earlier work showed that third through sixth grade children do not spontaneously engage in constructive inferential processing to discern when a piece of information is incomprehensible or inconsistent (Markman, 1977; 1979). More importantly, prior research revealed that performance is enhanced through systematic probes such as: 1) explicitly drawing attention to the existence of a problem, 2) requiring children to repeat the information so that the inconsistent pieces are activated in working memory simultaneously, 3) enactment and demonstration of the target information to aid mental processing. In this research I did not assess whether children detected the inconsistency between the new evidence and their existing belief set. Nevertheless, several features of the task as well as probes arguably facilitated children's encoding, comparison and integration of information

presented to them in the way shown by Markman (1977; 1979). First, the belief-contravening problems were enacted through visual aids displaying all pieces of information synchronously with the verbal script, presumably enabling children to follow and process information as the problem unfolds. Second, the new evidence was presented after children generated an inference they considered to follow from the premises and the picture depicting this evidence was placed on top of the picture depicting children's prediction. This feature of the task ensured that children engaged in the inferential processing required for the detection of inconsistency. Lastly, the resulting inconsistency was highlighted for them; they were explicitly told that the story was no longer correct, and they were invited to find a solution. These features of the task together with the fact that children rarely accepted both options and usually made clear choices are indicative of their ability to detect the inconsistency and their motivation to resolve it. During their exploration of the world, children frequently encounter new evidence/information that is incompatible with their existing knowledge. In line with what Piaget called the process of "assimilation and accommodation" and what Neo-Piagetians called "theory testing" (Gopnik & Meltzoff, 1997; Gopnik, Meltzoff, & Kuhl, 1999; Gopnik & Wellman, 1994), not only children but also adults find the presence of an inconsistency or uncertainty in their knowledge system unsettling and are motivated to revise some of their prior beliefs in light of new information (Loewenstein, 1994; Posner et al., 1982).

4.4 Do all belief types weigh the same in children's knowledge representations?

Despite children's ability and motivation to reinstate consistency in their belief set, results from the current study did not reveal a clear pattern in their reasoning during the belief-revision process – their responses indicated no salient preference for one belief over another. It is possible that the observed response pattern is due to the nature of the test questions. In the current work, children were always presented with two options that were equally logical solutions and based on explicit rejection of earlier beliefs. Some researchers argue that, unlike traditional methods using forced-choice questions, measuring individuals' belief-revision strategies using open-ended questions would enable them to reason flexibly about possible solutions to resolve the inconsistencies and provide us with richer data on the underlying cognitive process (Byrne & Walsh, 2002). For example, one study found that adults are more likely to raise doubts and generate possible reinterpretation of prior beliefs based on the given premises than directly

rejecting one of them. Similarly, children's reasoning in a belief-contravening paradigm like the one used in the current studies could be probed in several ways. First, inspired by Markman (1979), the test question could simply be presented open-ended (e.g., "Let's say/assume that the ball Chloe brings from her box to the table is dotted! (1) Does this make sense? Why? (2) What would you change in the story so that it makes sense?"). In this case, children's explanations and answers would be categorized in terms of the degree to which these are informed by children's belief in the general or particular premise. Second, the target premises in the paradigm could be presented using two puppets matched in reliability and knowledgeability, and given the evidence that leads to inconsistency, children could be asked which of the two puppets they think could be wrong and why. Although this version would still require children to choose among two options to resolve the inconsistency, it would have at least two advantages compared to the current procedure: it would 1) help children to respond more flexibly and free them from demand characteristics of the situation as they are not required to directly refute the information previously presented by an adult (experimenter), 2) prompt children to raise doubts about a pretend informant rather than merely refuting what was said. Considering children's limited capacity to produce fully informative explanations and articulate their underlying thinking at this age (e.g., Domberg, Köymen, & Tomasello, 2019), another possible future paradigm could present children with the additional option of providing an explanation for the inconsistent evidence in a way similar to how Khemlani & Johnson-Laird (2011) tested adults. For example, endorsement of an explanation such as "Perhaps, Chloe was confused about the boxes and mistakenly took a ball from Sophia's box instead of hers" would be a reinterpretation of the particular premise while belief in the general premise is still retained. On the other hand, endorsement of an explanation such as "Perhaps, unbeknownst to Chloe, someone put a dotted ball in her box" would be a reinterpretation of the general premise while belief to the particular premise is still retained.

One radical outcome to consider is that children's choices with the suggested procedural changes will still be random such that they will be as likely to endorse a reinterpretation/explanation regarding their beliefs based on generalizations/essential information as well as their beliefs based on particular observation/non-essential information to resolve an inconsistency. The implication of such an outcome would be one of the following: 1) children reason based on pure abstract logical principles during belief-revision process which overrides how their semantic

knowledge about how an entity is organized (i.e., realizing that both options are plausible logical solutions for the inconsistency) or 2) children treat all beliefs as equal in the revision process. I argue against both implications. First, it is unlikely that children between the ages of 4 to 7 years are fully capable of appreciating that both response options are viable logical solutions. Research shows that such sophisticated logical reasoning still develops from elementary school age through adolescence (Markovits et al., 2017). More importantly, it has been argued that when individuals engage in everyday reasoning (i.e., reasoning based on daily information rather than abstract content) their reasoning is inevitably influenced by their pre-existing knowledge and cognitive biases (Khemlani, Byrne, & Johnson-Laird, 2018). Therefore, it is unrealistic to expect that children's ability to follow abstract logical principles at this age is strong enough to override existing biases induced by the content of the information presented in the current studies.

Regarding the second implication of a persistent random pattern in children's reasoning, it is important to highlight that the belief-revision process, especially as measured in the current studies, invokes counterfactual thinking. Children are asked to imagine a possible world in which the new evidence holds true and re-construct their existing belief set in a coherent way by mutating some but not other beliefs. In this respect, individual's decision about which beliefs to revise is likely to be informed by the patterns and biases present in the human reasoning system in general, and those observed in counterfactual thinking more specifically. As posited by the Theory of Possible Worlds, beliefs are organized hierarchically and ranked in terms of their necessity when individuals generate alternatives to reality (Lewis, 1973, 1986 as cited in Swan et al., 2013). Moreover, research on counterfactual thinking with adults indicate that several biases are in play when individuals generate alternatives to reality. For example, individuals tend to mutate events in their counterfactual simulations that are exceptional rather than routine (Kahneman & Tversky, 1982), controllable rather than uncontrollable (Girotto, Legrenzi, & Rizzo, 1991; Mandel & Lehman, 1996; Roese, 1997), and based on enabling conditions rather than strong causes (e.g., Mandel & Lehman, 1996; McCloy & Byrne, 2002; N'gbala & Branscombe, 1995; Wells & Gavanski, 1989). While developmental work is scarce, there is some evidence suggesting that some similar biases are observed in children's counterfactual thinking (Guttentag & Ferrell, 2004; Meehan & Byrne, 2005; Nyhout & Ganea, 2020; Payir and Guttentag, 2019). These findings suggest that when adults and children generate a possible alternative world, they take into account various aspects of the situation and attribute differential

status to their beliefs accordingly. Therefore, it is unlikely that children's reasoning during belief-revision will be random.

A growing body of research draws attention to the importance of questions and explanations as underlying mechanisms of children's reasoning and learning (e.g., Chouinard, Harris, & Maratsos, 2007, Kelemen, 2019; Macris & Sobel, 2017). It has been shown that 4-5-year-old children actively seek plausible explanations during their daily conversations and in the presence of expectation-violating situations (Frazier, Gelman, & Wellman, 2016). In this respect, future research focusing on the possible explanations that children self-generate or evaluate in response to the unusual aspects of the new evidence has the potential to reveal a clearer pattern in children's reasoning when they reconcile new information with prior knowledge.

4.5 Children's revision of arbitrary and natural kind category representations

The ability to flexibly integrate new information into one's existing knowledge and change beliefs that no longer hold true in light of new evidence is crucial for human learning. The findings from the current work suggest that preschool age and early elementary school age children's initial category representations are not as resistant to the integration of new information as would be expected based on prior research . In Chapter 2, around half of the 5- and 7-year-old children and adults revised what they believed to be a true generalization about the target category (e.g., Chloe might have dotted balls as well), and in Chapter 3, around half of the 4- to 7-year-old children revised their initial belief about the category membership of a novel creature. The target categories in Chapter 2 were arbitrary, i.e., balls belonging to Chloe and knights working for King William both represent socially, conventionally formed group of entities. Moreover, the critical features of these categories were superficial, e.g., pattern of the balls/hat color of the knights. In this sense, it is not unexpected that children's (and adults') beliefs based on the generalizations about these target categories were open to revision. On the other hand, in Chapter 3, children were presented with natural/kind categories, i.e., two novel kinds of creatures. Research has shown that children's expectation of natural categories is different from arbitrary categories such that they attribute more coherence to the former and their beliefs about these categories are relatively more essentialist in nature (e.g., Kalish, 1998; Tarlowski, 2018). In this sense, overall, one would expect a greater resistance to revision of

beliefs that pertain to natural categories. More importantly, Chapter 3 compared the relative strength of nonobvious, internal properties (e.g., number of bones) and obvious, surface properties (e.g., color of glasses) in determining whether children revised their prior beliefs. It has been shown that as young as 4 years of age, children understand that internal properties are a critical aspect of defining a natural kind category (Diesendruck, Gelman, & Lebowitz, 1998), and relatedly, compared to its surface properties, differences in the internal properties of an entity are more likely to affect its identity (Gelman & Wellman, 1991). In line with these findings, children were found to favor essential properties over non-essential properties when identifying the novel exemplar when these properties were presented simultaneously (Chapter 3, control condition). However, the relative status they attributed to these two types of properties during categorization did not manifest itself in their reasoning during the process of belief-revision. Children did not have a robust preference to retain their category beliefs based on essential property; around half of the time, they revised their initial categorization in light of the non-essential property (e.g., A novel creature initially believed to be a Morseth due to having two bones was later categorized as a Scoobit because it wore yellow glasses instead of purple, Chapter 3, essential condition). Nor did they show a robust tendency to revise their category beliefs based on a non-essential property; around half of the time, they retained their initial categorization despite an incompatible essential property (e.g., A novel creature initially believed to be a Morseth because it wore purples glasses was still categorized as a Morseth despite learning that it has three bones inside its body, Chapter 3, non-essential condition).

The observed random pattern in children's revision of their prior beliefs could be due to the arbitrariness of the paradigm. Research on the influence of artificial vs real-world content in individuals' belief-revision strategies suggests that when the content of beliefs is artificial, it is less likely that some beliefs are considered as more important than others (Revlin et al., 2005). On the other hand, realistic beliefs are considered as relatively long-term generalizations because they are embedded in the coherent and causal structure of individuals' existing semantic knowledge of the world. Developmental theories emphasize the role of causality in shaping children's beliefs about the world around them and argue that children actively seek out information that would reveal the underlying causal structure of their environment (e.g., Keil, 1998; Gelman, 2003; Bloom, 1996). In this respect, it is possible that children attribute

differential weight to various beliefs in their category-based representations depending on the extent to which these beliefs are causally related to the category.

Research on children's learning of category information provides supporting evidence for this argument. A study showed that when learning about an animal kind, children had a strong preference for information that is causally related to the kind (Alvarez & Booth, 2015). For example, children chose to learn from an informant providing causal properties of a novel entity (e.g., has a tail that makes a rattling sound to scare other animals away) over an informant who provides non-causal properties (e.g., has a tail that bounces up and down on the ground as it walks). Furthermore, another study showed that children were more likely to consider causally interrelated features, e.g., "have sharp teeth" and "eat meat", as more definitive of an animal kind category than causally non-interrelated features, e.g., "have pointed ears" and "have spots" (Murphy & Allopena, 1994).

Taken these findings together, it is possible that children would prioritize beliefs which are causally linked to their category representation over beliefs which lack such a causal link. The current work, and in particular Chapter 3, did not manipulate the causality of the relation between target beliefs and the respective categories but instead causality was implicated in the distinction between essential and non-essential properties. The absence of a clear preference for essential beliefs in children's reasoning implies that the differential causality that essential and non-essential properties entail was not accessible to children in the current study. As a result, children might have assumed that both types of beliefs were equally dispensable in the face of inconsistent evidence. An interesting future direction for research would be to explore whether highlighting the causal difference between essential and non-essential properties would lead to a clearer pattern in children's reasoning during the process of belief-revision.

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Appendices

Appendix A. Demographic form used in Experiment 1-3

Child's Date of Birth: Month _____ Day _____ Year _____ Date (mm/dd/yy):

Ethnicity			
Your Child	Yourself	Your Partner (leave blank if none)	
❑	❑	❑	Aboriginal (e.g., First Nations, Métis, Inuk)
❑	❑	❑	Arab
❑	❑	❑	Black
❑	❑	❑	Chinese
❑	❑	❑	Filipino
❑	❑	❑	Japanese
❑	❑	❑	Korean
❑	❑	❑	Latin American
❑	❑	❑	Southeast Asian (e.g., Vietnamese, Cambodian, Malaysian, Laotian)
❑	❑	❑	South Asian (e.g., East Indian, Pakistani, Sri Lankan)
❑	❑	❑	West Asian (e.g., Iranian, Afghan)
❑	❑	❑	White
			Mixed Ethnicity (Please Specify)
			Other (Please Specify)

Gender		
Your Child	Yourself	Your Partner (leave blank if none)

Please indicate your highest level of education completed	
Yourself	Your Partner (leave blank if none)
❑No formal schooling ❑Partial High School ❑High School Diploma/GED ❑College Diploma ❑Bachelor's Degree ❑Master's Degree ❑Ph.D., M.D., Law Degree	❑No formal schooling ❑Partial High School ❑High School Diploma/GED ❑College Diploma ❑Bachelor's Degree ❑Master's Degree ❑Ph.D., M.D., Law Degree
Please indicate your current employment status	
Yourself	Your Partner (leave blank if none)
❑ Employed full time ❑ Employed part-time ❑ Stay-at-home parent ❑ Not currently employed ❑ A student ❑ Retired ❑ Self-employed	❑ Employed full time ❑ Employed part-time ❑ Stay-at-home parent ❑ Not currently employed ❑ A student ❑ Retired ❑ Self-employed
Your Occupation(s):	Your Partner's Occupation(s):

Please indicate your annual household income for the most recent year						
❑less than $24,999	❑ $25,000 -$49,999	❑ $50,000 -$74,999	❑ $75,000 -$99,999	❑ $100,000 - $124,999	❑ $125,000 -$149,999	❑ $150,000 or more

LANGUAGE ENVIRONMENT AT HOME

Has your child been exposed to 2 or more languages at any time since birth? **Y** or **N**

During a typical week, reflect on the language encounters your child has at **home**. Who is your child speaking with? In what language? How often do these interactions occur? When did these interactions begin? **Please skip the table if your child has only heard English since birth.**

Family Member	**Language(s) used**	**# days per week**	**# of hours per day**	**Since when? (in months)**
e.g. Mother	*Spanish*	*5*	*7*	*Since birth*
e.g. Nanny	*French*	*3*	*5*	*Since 6 months*

Typical day for your child:

a. Wake up time: _____ b. Bed time: _____

AT DAYCARE/PRESCHOOL/SCHOOL

Does your child attend daycare/preschool/school? **Y** or **N** Since when?_____

How many hours per day does your child attend? _____

How many days per week does your child attend? _____

What language(s) are **spoken to your child** at the daycare/preschool/school?_____

MEDIA

In what language do **you** primarily watch/listen to:

TV/Movies : _____ Radio: _____

How many hours during a day does **your child**:

Use an iPad/tablet/eBook _____ In what language(s)_____

Play on a computer _____ In what language(s)_____

Reads or is read books to (e.g. eBook) _____ In what language(s)_____

IN GENERAL

What languages does your child prefer or seem to **understand** best?_____

If your child **speaks** any languages other than English, what are they?_____

How many hours during a day does your child **speak** these languages?_____

BASIC INFORMATION

Was your child born at term? **YES / NO** Weeks: _____ Weight: _____

Your child's birth order (circle one): Only child 1st 2nd Other (please specific _____)

Number of children in the family home _____ Number of adults in the family home _____

Did you experience any major pregnancy or birth complications? If **YES**, please describe.

_____

Does your child experience chronic ear infections (5 or more)? If **YES**, please describe.

_____

Has your child ever gotten intervention for their ear infections (e.g., tube insertion)? If **YES**, please describe.

_____

Is there any reason to suspect that your child may have hearing loss? **Y** or **N**

_____

Has your child had any major illnesses, hospitalization, diagnosed disabilities, or speech/language delays? If **YES**, please describe.

_____

Have you or any member of your extended family (e.g., child's siblings, grandmother, father) been diagnosed with any behavioural impairment, neurological impairment, or language or learning disability? If **YES**, please describe.

_____

Are there any current concerns about your child's learning or development (including speech and language delay)? If **YES**, please describe. _____

CAREGIVER INFORMATION

Who participates in the day-to-day care of your child? (Check all that apply):

____Mother/Guardian

____Father/Guardian

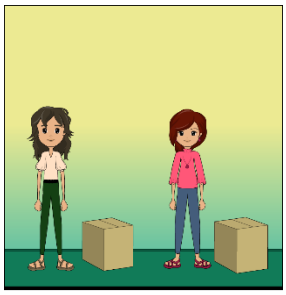
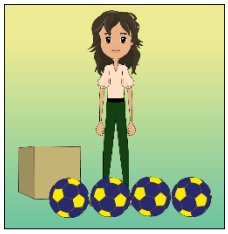
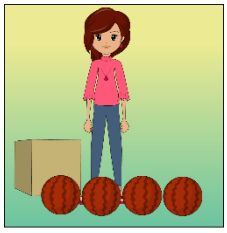
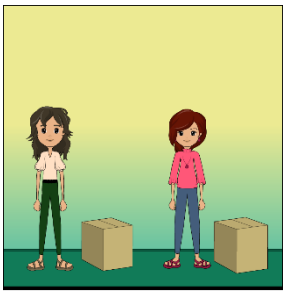
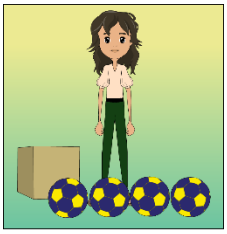
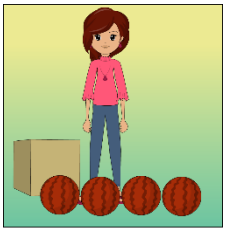
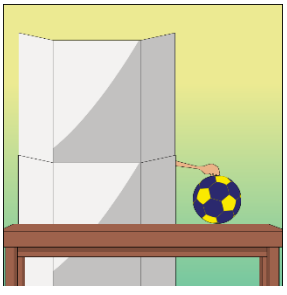
____Outside-the home caregiver (e.g., family provider in the persons home) (__ hours/week)

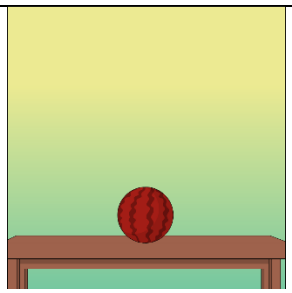
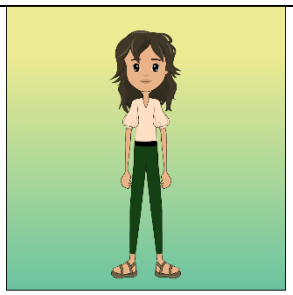
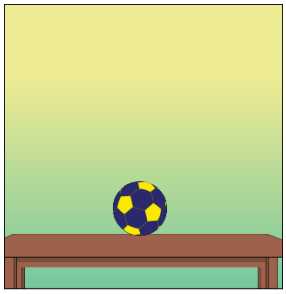
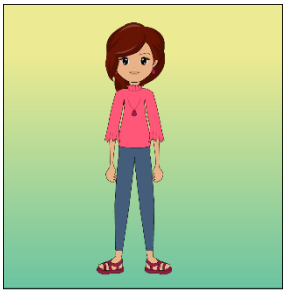
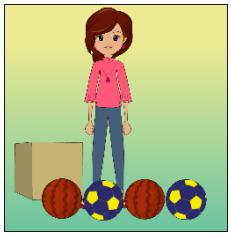
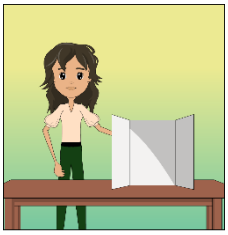
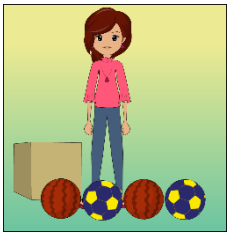
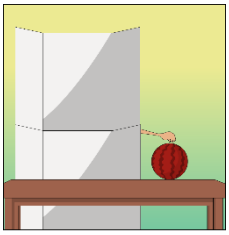
____Child care center (_____hours/week)

____Non-parent caregiver (e.g., grandparent, nanny) in your home (_____hours/week)

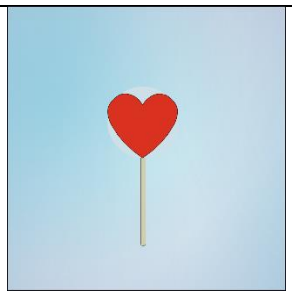
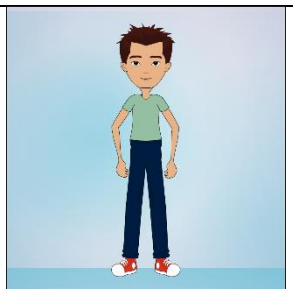
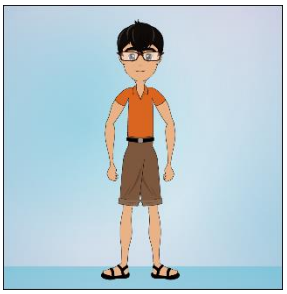
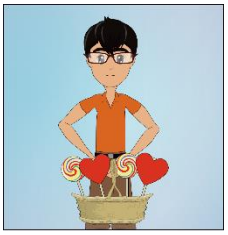
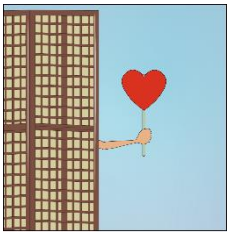
____Other, please specify:_____ (_____hours/week)

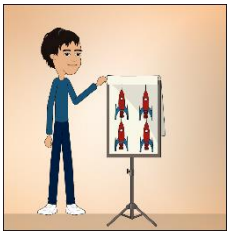
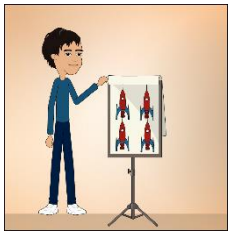
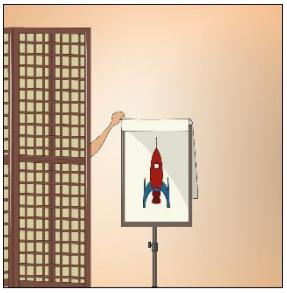
Appendix B. Story stimuli used in Experiment 1 of Chapter 2

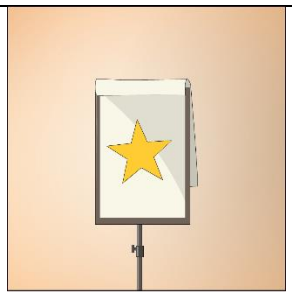
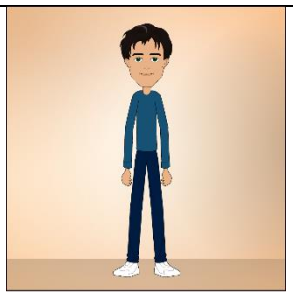
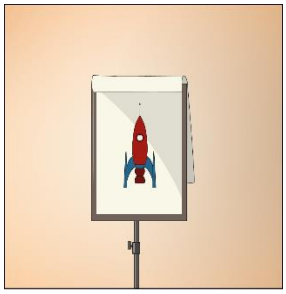
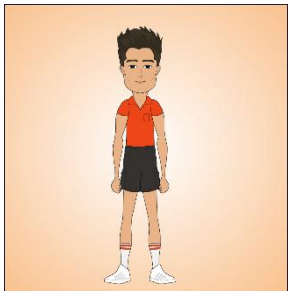
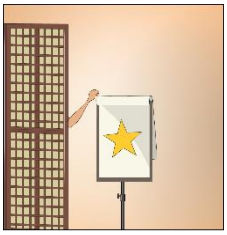
Balls	Modus Ponens	Modus Tollens
Introduction	Here is Chloe and Sophia. They have lots of balls inside their boxes.  All of Sophia's balls are dotted. All of Chloe's balls are striped.  	Here is Chloe and Sophia. They have lots of balls inside their boxes.  All of Sophia's balls are dotted. All of Chloe's balls are striped.  
General premise	So, in the story, all of Chloe's balls are striped. [p → q]	So, in the story, all of Chloe's balls are striped. [p → q]
Particular premise	Chloe brings a ball from her box to the table. [p] 	One of them brings a dotted ball from her box to the table. [not q] 
Inference question	Do you think the ball that Chloe brings from her box to the table is striped or dotted? Correct answer: Striped [q]	Who do you think brings the dotted to the table? Chloe or Sophia? Correct answer: Sophia [not p]

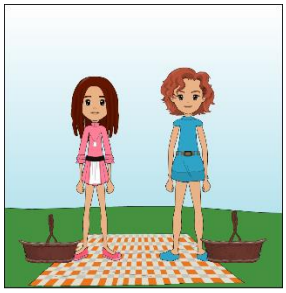
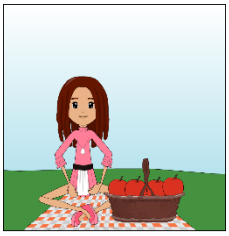
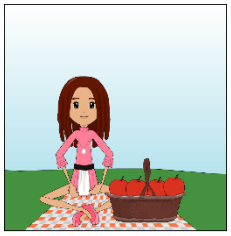
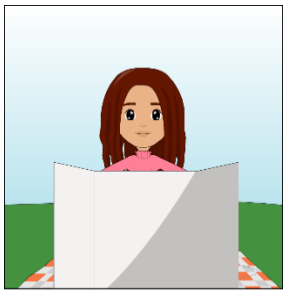
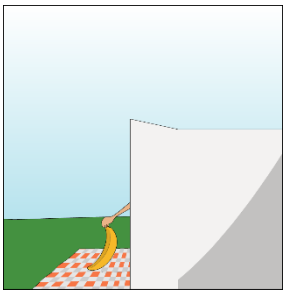
		
Incompatible evidence	Let's say/assume that the ball Chloe brings from her box to the table is dotted! [E puts the following picture on top of the previous one] 	Let's say/assume that it is Chloe who brings the dotted ball from her box to the table! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we fix/change in the story? We either change the story so that Chloe has dotted balls as well or we change it so that it is Sophia who brings a ball to the table.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]	What should we fix/change in the story? We either change the story so that Chloe has dotted balls as well or we change it so that the ball on the table is striped.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]

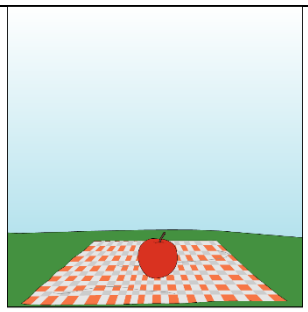
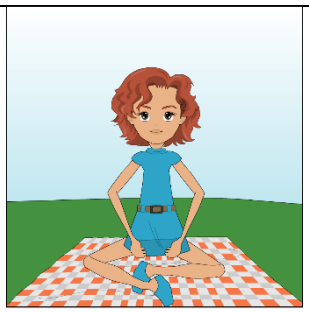
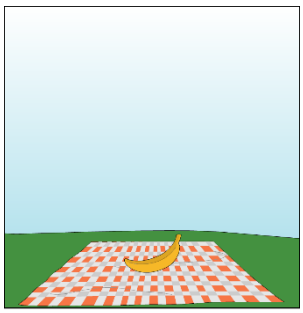
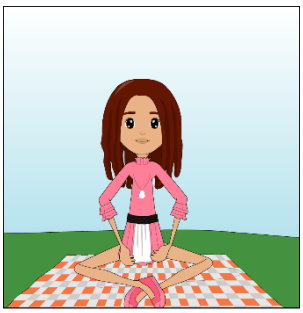
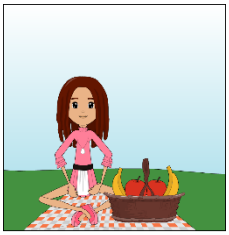
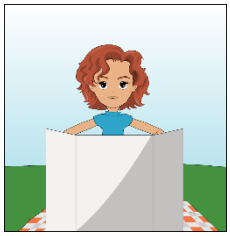
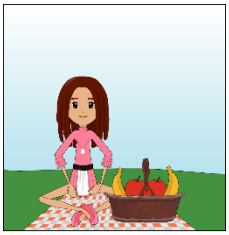
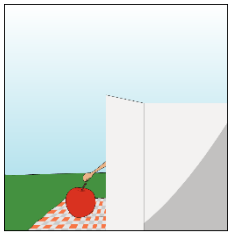
Lollipops	Modus Ponens	Modus Tollens
Introduction	Here is Sam and Alex. They have lots of lollipops inside their baskets.  All of Sam's lollipops are round. All of Alex's lollipops are heart-shape.  	Here is Sam and Alex. They have lots of lollipops inside their baskets.  All of Sam's lollipops are round. All of Alex's lollipops are heart-shape.  
General premise	So, in the story, all of Alex's lollipops are heart-shape. [p → q]	So, in the story, all of Alex's lollipops are heart-shape. [p → q]
Particular premise	Alex brings out a lollipop from his basket. [p] 	One of them brings out a round lollipop from his basket. [not q] 
Inference question	Do you think the lollipop that Alex brings out from his basket is heart-shape or round? Correct answer: Heart-shape [q]	Who do you think brings out the round lollipop from his basket? Alex or Sam? Correct answer: Sam [not p]

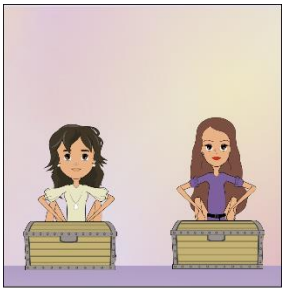
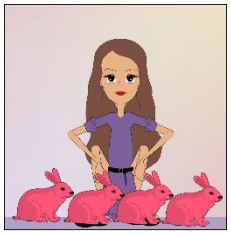
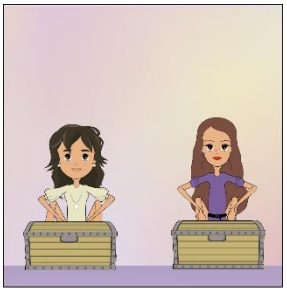
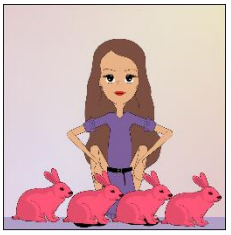
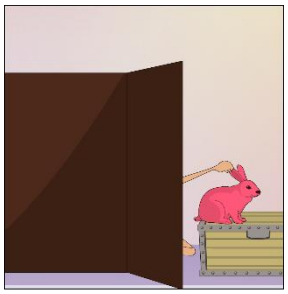
		
Incompatible evidence	Let's say/assume that the lollipop that Alex brings out is round. [E puts the following picture on top of the previous one] 	Let's say/assume that it is Alex who brings out the round lollipop! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we fix/change in the story? We either change the story so that Alex has round lollipops as well or we change it so that it is Sam who brings out a lollipop.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]	What should we fix/change in the story? We either change the story so that Alex has round lollipops as well or we change it so that the lollipops that is brought out is heart-shape.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]

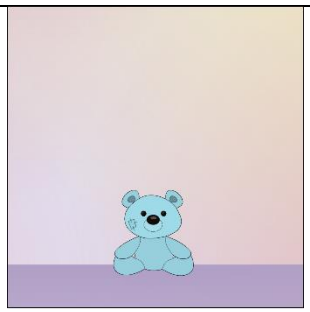
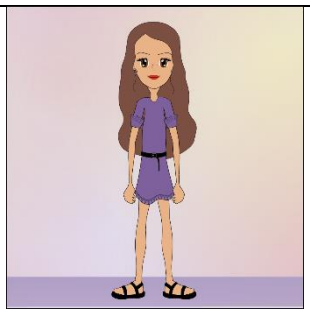
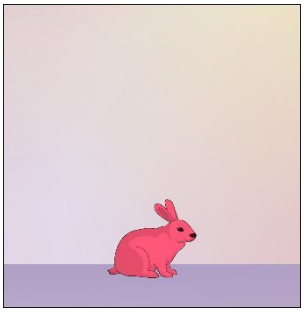
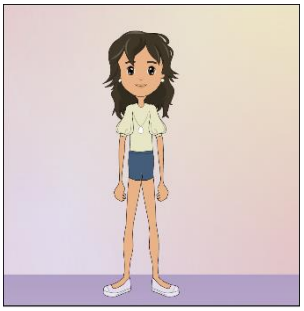
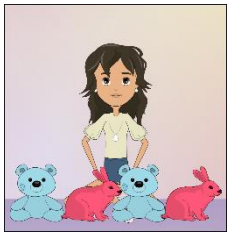
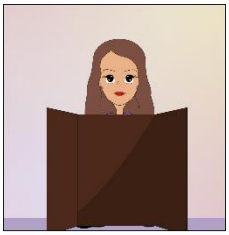
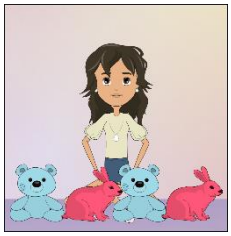
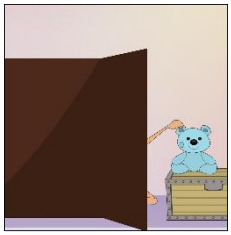
Stickers	Modus Ponens	Modus Tollens
Introduction	Here is Max and Lucas. They have lots of stickers.  All of Lucas's stickers are spaceships. All of Max's stickers are stars.  	Here is Max and Lucas. They have lots of stickers.  All of Lucas's stickers are spaceships. All of Max's stickers are stars.  
General premise	So, in the story, all of Max's stickers are stars. [p → q]	So, in the story, all of Max's stickers are stars. [p → q]
Particular premise	Max picks a sticker from his pile to put on a piece of paper. [p] 	One of them picks a spaceship sticker from his pile to put on a piece of paper. [not q] 
Inference question	Do you think the sticker that Max picks from his pile is a star or a spaceship? Correct answer: Star [q]	Who do you think takes the spaceship sticker from his pile? Max or Lucas? Correct answer: Lucas [not p]

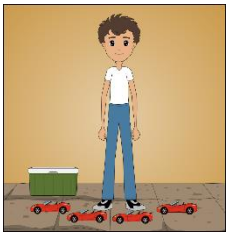
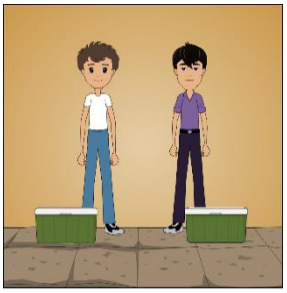
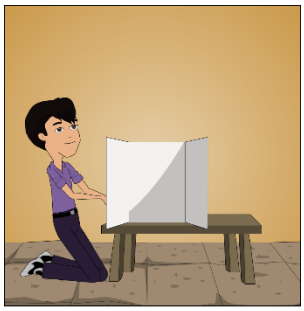
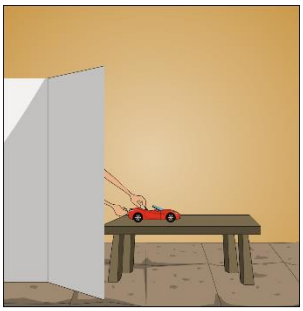
		
Incompatible evidence	Let's say/assume that the sticker that Max picks is a spaceship! [E puts the following picture on top of the previous one] 	Let's say/assume that it is Max who picks the spaceship sticker! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we fix/change in the story? We either change the story so that Max has spaceship stickers as well or we change it so that it is Lucas who picks a sticker.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]	What should we fix/change in the story? We either change the story so that Max has spaceship stickers as well or we change it so that the sticker on the paper is a star.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]

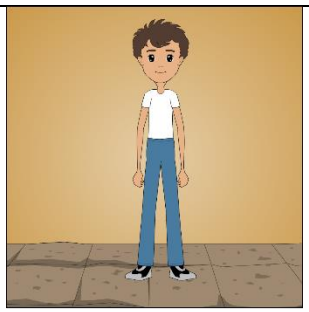
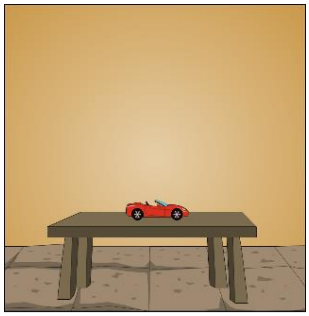
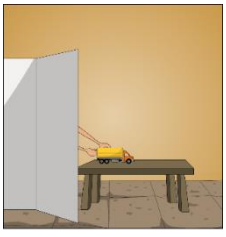
Fruits	Modus Ponens	Modus Tollens
Introduction	Here is Emma and Irene. They have lots of fruits in their baskets.  All of Irene's fruits are bananas. All of Emma's fruits are apples.  	Here is Emma and Irene. They have lots of fruits in their baskets.  All of Irene's fruits are bananas. All of Emma's fruits are apples.  
General premise	So, in the story, all of Emma's fruits are apples. [p → q]	So, in the story, all of Emma's fruits are apples. [p → q]
Particular premise	Emma takes a fruit from her basket. [p] 	One of them takes a banana from her basket. [not q] 
Inference question	Do you think the fruit that Emma takes from her basket is a banana or an apple? Correct answer: Apple [q]	Who do you think takes the banana from her basket? Emma or Irene? Correct answer: Irene [not p]

		
Incompatible evidence	Let's say/assume that the fruit that Emma takes from her basket is a banana! [E puts the following picture on top of the previous one] 	Let's say/assume that it is Emma who takes the banana from her basket! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we change in the story? We either change the story so that Emma has bananas as well or we change it so that it is Irene who takes a fruit from her basket.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]	What should we change in the story? We either change the story so that Emma has bananas as well or we change it so that the fruit that is taken from the basket is an apple.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]

Animals	Modus Ponens	Modus Tollens
Introduction	Here is Mia and Charlotte. They have lots of stuffed animals.  All of Charlotte's stuffed animals are bunnies. All of Mia's stuffed animals are bears.  	Here is Mia and Charlotte. They have lots of stuffed animals.  All of Charlotte's stuffed animals are bunnies. All of Mia's stuffed animals are bears.  
General premise	So, in the story, all of Mia's stuffed animals are bears. [p → q]	So, in the story, all of Mia's stuffed animals are bears. [p → q]
Particular premise	Mia takes out a stuffed animal from her toy box. [p] 	One of them takes out a stuffed bunny from her toy box. [not q] 
Inference question	Do you think the stuffed animal that Mia takes out from her toy box is a bunny or a bear? Correct answer: Bear [q]	Who do you think takes out the stuffed bunny from her toy box? Mia or Charlotte? Correct answer: Charlotte [not p]

		
Incompatible evidence	Let's say/assume that the stuffed animal that Mia takes out is a bunny! [E puts the following picture on top of the previous one] 	Let's say/assume that it is Mia who takes out the stuffed bunny! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we change in the story? We either change the story so that Mia has bunnies as well or we change it so that it is Charlotte who takes out a stuffed animal.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]	What should we change in the story? We either change the story so that Mia has bunnies as well or we change it so that the stuffed animal that is taken out is a bear.   What do you think? Which part of the story we should change, this or this? [Pointing to the two possible options depicted on the pictures]

Toy Cars	Modus Ponens	Modus Tollens
Introduction	Here is Liam and Jacob. They have lots of toy cars in their boxes.  All of Jacob's toys are race cars. All of Liam's toys are trucks.  	Here is Liam and Jacob. They have lots of toy cars in their boxes.  All of Jacob's toys are race cars. All of Liam's toys are trucks.  
General premise	So, in the story, all of Liam's toys are trucks. [p → q]	So, in the story, all of Liam's toys are trucks. [p → q]
Particular premise	Liam brings a toy from his box to the table. [p] 	One of them brings a race car from his box to the table. [not q] 
Inference question	Do you think the toy that Liam brings from his box to the table is a race car or a truck? Correct answer: Truck [q]	Who do you think brings the race car from his box to the table? Jacob or Liam? Correct answer: Jacob [not p]

		
Incompatible evidence	Let's say/assume that the toy that Liam brings to the table is a race car! [E puts the following picture on top of the previous one] 	Let's say/assume that it is Liam who brings the race car to the table! [E puts the following picture on top of the previous one] 
Inconsistency highlighted	Then, it does not fit with the rest of the story.	Then, it does not fit with the rest of the story.
Test question	What should we change in the story? We either change the story so that Liam has race cars as well or we change it so that it is Jacob who brings a toy to the table.   What do you think? Which part of the story we should change, this or this? Pointing to the two possible options depicted on the pictures]	What should we change in the story? We either change the story so that Liam has race cars as well or we change it so that the toy that is brought to the table is a truck.   What do you think? Which part of the story we should change, this or this? [Pointing to he two possible options depicted on the pictures]

Appendix C. Story stimuli used in Experiment 2 of Chapter 2

Story 1: The Knights Story [Modus Tollens Version]

Narrative

"Once upon a time there was a very pretty country, Fantasia. The trees and bushes grew beautiful, there was food for everybody, and all the people lived in peace. The king of that country was called King William. King William was a good and fair man, who did everything for the people who lived in his country. The people were happy with their king and admired him. Next to that country was the country of another king, King Igor. King Igor was a bad and cruel man. In his country things did not go as well. The trees and bushes grew bad or remained barren, and there was not enough food for everybody, because King Igor took all the money away from the people who lived in his country. King Igor was very jealous of King William. King Igor also wanted a country where everything went that well. That's why he decided to attack them. He wanted to capture King William and burn the land. Therefore, he chose the most evil men in his prison and sent them to Fantasia, the country of King William. The evil men of King Igor looked dangerous. They were riding black horses, wearing black hats, and carrying battle-axes to fight. All the knights of King Igor went to the land of the good King William to fight. However, the brave knights of King William fought back. They looked really beautiful and strong. They rode white horses, wore white hats, and had swords to fight. The good knights of King William succeed in driving away the evil men in their country and they could keep their land. Together with King William they celebrated their victory."

Memory-question

"Can you tell me what you heard [in the story]?"

a. "Who was the good King?
   What was the colour of the hats of the knights of King William?
b. "Who was the bad King?
   What was the colour of the hats of the knights of King Igor?"

Experimental Task

2a. "So, in the story all good knights of King William wore a white hat."

2b. "This knight wears a black hat."

2c. "This means that this knight works for the bad King Igor."

"Let's pretend now that [literally: Let's now do as if …]"

2d. "….this knight fights with the good king, King William [instead of with the bad king]."

Check-question 1

"Now the story is not correct anymore… Can you tell me why? [Because the story said that all knights of King William wear a white hat and this knight wears a black hat, but we pretend now that he also works for King William.]"

Experimental Task - continuation

"We have two options to solve this problem, to make it correct again."

a. "Either the knights of King William can also wear a black hat now."
b. "Or we give this knight a white hat."

"Which option do you chose, do you prefer?"

Check-question 2

"Why is the story correct again?"

Story 2: The Heroes Story [Modus Ponens Version]

Narrative

"In the Old West there was a city where a lot of people lived. However, the people were not that happy there, because they had a big problem. The problem was that their stagecoaches were surprised by terrible thieves. Those stagecoaches were usually filled with money and food for the people in the town. The thieves held up the coaches and took all the money, and the horses. The thieves all wanted to look dangerous, so they rode on black horses. They also carried a black hat and an axe. In this town also lived a hero and he thought there had to be an end to these thieves taking everything away from the coaches. He wanted to throw all of the thieves in prison, as they should be. The hero called for a group of good, strong men who could help him to imprison the thieves. All the men who went out to help the hero liked to look beautiful and strong, so they rode on white horses, wore a white hat, and carried a sword. When the hero had collected enough strong men, they set up a plan. A few of them hid in a coach and the other part hid in the bushes and behind the trees. When the coach passed the road, the thieves attacked them again. But this

time the heroes jumped out of the bushes and out of the coach and surrounded the thieves. The thieves were brought to prison, and from that day on coaches were never surprised, and the people in the town were happy again."

Memory-question

"Can you tell me what you heard [in the story]?"

a. "Who was the good person? [hero]
   What was the colour of the heroes' hats?"

b. "Who was the bad person? [thieve]
   What was the colour of the thieves' hats?"

Experimental Task

2a. "So in the story that all heroes wore a white hat."

2b. "This person is a hero."

2c. "He wears a white hat."

"Let's pretend now that [literally: Let's now do as if …]"

2d. "…this person wears a black hat."

Check-question 1

"Now the story is not correct anymore… Can you tell me why? [Because the story said that that all heroes wear a white hat and this person is a hero … but we pretend now that he wears a black hat.]"

Experimental Task - continuation

"We have two options to solve this problem, to make it correct again."

a. "Either, heroes can also wear a black hat now."

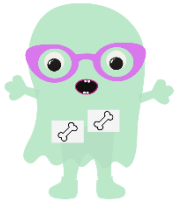
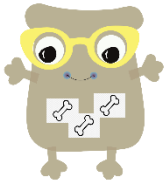
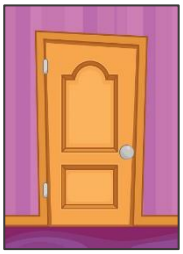
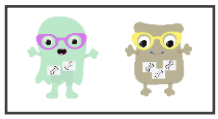
b. "Or this person is a thief from now on."

"Which option do you chose, do you prefer?"

Check-question 2

"Why is the story correct again?"

Appendix D. An example trial in the control condition of Chapter 3

	Control Condition
Introduction of the two target kind categories	  Morseths and Scoobits, two different creatures. Morseths and Scoobits are very different from one another. This is a Morseth. Morseths have two bones inside their body. See? Here are two bones inside its body. And Morseths wear purple glasses on their eyes. See? And this is a Scoobit. Scoobits have three bones inside their body. See? And Scoobits wear yellow glasses on their eyes. See?
Introduction of the new exemplar	   Now, there is a new creature behind this door. Max does not know whether this creature is a Morseth or a Scoobit. We will help him find out. There are cues in these envelopes. Let's open one of them.
Categorization	  Look, the creature behind the door has three bones inside its body and wears purple glasses on its eyes. What do you think it is? A Morseth or a Scoobit?  

Appendix E. List of stories used in Chapter 3

Story type	Kind category #1	Kind category #2
Essential properties differ qualitatively	Crullets have small stomach inside their bodies. Crullets wear orange bowties on their necks.	Bongos have big stomach inside their bodies. Bongos wear green bowties on their necks.
	Blickets have big brains inside their heads. Blickets wear blue scarves on their necks.	Mokis have small brains inside their heads. Mokis wear blue scarves on their necks.
Essential properties differ quantitatively	Plinkers have two lungs inside their bodies. Plinkers wear white hats on their heads.	Zarpies have one lung inside their bodies. Zarpies wear black hats on their heads.
	Morseths have two bones inside their bodies. Morseths wear purples glasses on their eyes.	Scoobits have three bones inside their bodies. Scoobits wear yellow glasses on their eyes.