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Conceptual influences on induction: A case for a late onset ☆

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ABSTRACT

This research examines the mechanism of early induction, the development of induction, and the ways attentional and conceptual factors contribute to induction across development. Different theoretical views offer different answers to these questions. Six experiments with 4- and 5-year-olds, 7-year-olds and adults ($N = 208$) test these competing theories by teaching categories for which category membership and perceptual similarity are in conflict, and varying orthogonally conceptual and attentional factors that may potentially affect inductive inference. The results suggest that early induction is similarity-based; conceptual information plays a negligible role in early induction, but its role increases gradually, with the 7-year-olds being a transitional group. And finally, there is substantial contribution of attention to the development of induction: only adults, but not children, could perform category-based induction without attentional support. Therefore, category-based induction exhibits protracted development, with attentional factors contributing early in development and conceptual factors contributing later in development. These results are discussed in relation to existing theories of development of inductive inference and broader theoretical views on cognitive development.

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1. Introduction

The reported research focuses on the development of induction. It was conducted within a framework of a long-standing debate about the origins of early inductive generalization, its mechanism, and development (see, Booth, 2014; Gelman, 1988; Gelman & Davidson, 2013; Gelman & Heyman, 1999; Gelman & Markman, 1986; Gelman & Medin, 1993; Gelman & Waxman, 2007; Graham, Booth, & Waxman, 2012; Keates & Graham, 2008; Noles & Gelman, 2012a 2012b; Waxman & Gelman, 2009; for one side of the debate; see also Badger & Shapiro, 2012; Deng & Sloutsky, 2012, 2013; Fisher, 2010, 2011; Fisher, Matlen, & Godwin, 2011; Fisher & Sloutsky, 2005; Jones & Smith, 1993; Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky, 2009; Sloutsky, 2010; Sloutsky & Fisher, 2004a, 2004b, 2008, 2012a, 2012b; Sloutsky, Kloos, & Fisher, 2007a, 2007b; Sloutsky & Lo, 1999; Sloutsky, Lo, & Fisher, 2001; Sloutsky & Napolitano, 2003, for another side of the debate). In the broadest possible terms, the two positions differ on whether induction (as well as categorization and word learning) is guided by *a priori* domain-specific knowledge exhibiting an early onset, or whether it is a product of domain-general learning, with domain-specific knowledge being a product rather than precondition of development. In this research we intended to move the field forward by providing insights about the development of induction and adjudicating between these broad views.

1.1. Theoretical approaches to induction and its development

Inductive generalization is a key cognitive ability: it enables generation of new knowledge on the basis of limited data and extension of this knowledge to novel situations. For example, upon observing a red-tailed hawk preying on small birds, one may expect other hawks (and perhaps falcons and eagles) to be predators as well.

Although it is well established that induction appears early in development (Gelman, 2004b, 1988; Gelman & Markman, 1986; Mandler & McDonough, 1996; Sloutsky & Fisher, 2004a; Welder & Graham, 2001), many important questions remain. What is the mechanism of induction and does it change over the course of development? If induction undergoes development, what changes, how, and why? And what is the role of language in this process? Answers to these questions are theoretically consequential for understanding the development of inductive generalization as well as for a more general theory of cognitive development. Two broad classes of answers have emerged, reflecting two different views on cognitive development.

According to one class of answers (often referred to as the *knowledge-based* approach), when the task is to generalize properties of some natural kind categories (such as animal kinds), induction is driven by conceptual knowledge. This knowledge is implemented as a set of conceptual assumptions, whose origin is unknown: it has been argued that these assumptions do not stem from parental input (Gelman, Coley, Rosengren, Hartman, & Pappas, 1998; see also Gelman, 2004; Murphy, 2002, for reviews). Two of these assumptions are critical for inductive inference. First, there is a category assumption: young children are said to believe that individuals belong to more general categories, with members of the same category sharing many important properties, especially if the category is a natural kind. And second, there is a linguistic assumption: young children are said to believe that count nouns denote categories (e.g. the word *dog* refers to a class rather than to a single individual). Therefore, when performing inductive generalizations, people, including young children, first identify the category of an entity (using either provided or self-generated labels) and then generalize properties of the entity to other members of the identified category. In short, according to this view, induction is based on prior categorization of presented entities, and is thus category-based.

According to another class of answers (often referred to as the *similarity-based* approach), conceptual knowledge (e.g., knowledge that members of the same category share important properties and that these properties may differ for natural kinds and artifacts) is a product rather than a precondition of development and learning. Therefore, conceptual knowledge is not *a priori* and it does not explain the development of induction, but rather itself needs an explanation. The development (including acquisition of conceptual knowledge) is grounded in powerful learning mechanisms, such as statistical, attentional, and associative learning (French, Mareschal, Mermillod, & Quinn, 2004;

Mareschal, Quinn, & French, 2002; McClelland & Rogers, 2003; Sloutsky & Fisher, 2004a; Smith, 1989; Smith, Jones, & Landau, 1996). One specific proposal within this approach is that early in development, both induction and categorization are based on the overall similarity of compared entities (Sloutsky & Fisher, 2004a; Sloutsky et al., 2001, 2007a). According to this view, similarity is a good starting point that helps getting the process off the ground and does not preclude acquisition of conceptual knowledge later in development.

Proponents of the similarity-based view also believe that linguistic labels may affect induction, but the mechanism of these effects is radically different from the one proposed within the knowledge-based approach. According to the similarity-based approach, early in development labels could function as features of objects contributing to the overall similarity among items, rather than as symbols denoting category membership. Support for this claim comes from findings that (a) young children, but not adults, perceive identically labeled entities as looking more alike than differently labeled entities (Sloutsky & Fisher, 2004a; Sloutsky & Lo, 1999; Sloutsky et al., 2001) and (b) words and other auditory stimuli affect processing of visual information (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2007, 2008; Sloutsky & Napolitano, 2003).

In addition to different mechanisms of early induction, the two approaches differ with respect to development, specifically to what develops and when. The knowledge-based approach advocates for an early onset of conceptual contributions and little developmental change: whenever developmental change occurs, it is linked to the acquisition or refinement of domain-specific knowledge (Carey, 1985; Gelman & Davidson, 2013; Inagaki & Hatano, 2002; Keil, 1981) or the emergence of more sophisticated induction strategies (e.g., López, Gelman, Gutheil, & Smith, 1992). However, on the basis of existing evidence for protracted development of category-based induction (Badger & Shapiro, 2012; Fisher & Sloutsky, 2005; Sloutsky et al., 2007a), the similarity-based approach argues that, in addition to acquisition and refinement of domain knowledge (e.g., Fisher, Godwin, Matlen, & Unger, 2015), development of induction (as well as categorization) is driven by changes in more basic cognitive processes, such as attention, memory, and cognitive control (see Deng & Sloutsky, 2015; Fisher, Godwin, & Matlen, 2015; Kloos & Sloutsky, 2008; Sloutsky & Fisher, 2004b; Smith & Samuelson, 2000, for relevant discussions).

Despite multiple important differences between the two positions, there are a number of commonalities, which make the task of adjudicating between these positions quite difficult. First, proponents of both positions expect labels to affect induction (although the hypothesized mechanisms of these effects differ across the positions). And second, similarity and conceptual information do not have to be mutually exclusive; in fact, proponents of conceptual accounts agree that similarity plays at least some role in early inductive inference (e.g., Gelman & Davidson, 2013; Gelman & Medin, 1993). Therefore, reliance on either labels or on perceptual information is insufficient for unambiguously distinguishing between the two positions.

1.2. Attempts to distinguish between these proposals

In an attempt to provide a more definitive test of both positions, Sloutsky et al. (2007a, hereafter SKF) introduced a new paradigm. The paradigm was based on two major ideas. The first major idea was to make labeling during induction unnecessary by providing participants (4- and 5-year-olds and adults) with a direct access to category information. This was achieved by teaching participants novel natural-kind categories that had a clear category-inclusion rule, which could be used during induction to access category information. The second major idea was to decouple appearance and category information: neither categorization nor induction could be achieved by matching appearances (or even single features) of compared items – participants had to rely on a relational category-inclusion rule.

Once participants learned the category, they were presented with an induction task, in which category membership was pitted against appearance similarity. The results were clear: despite learning the categories (and retaining this knowledge until after the end of the experiment), 4- and 5-year-olds did not use this information in the induction task; instead they based their induction on appearance information. It was concluded that early induction is based on similarity rather than on a common category.

However, these findings have been criticized for introducing artificial rather than natural kind categories and for not providing children with sufficient conceptual information (Gelman & Waxman, 2007). It was argued that, unless the category itself is clearly conceptually-based, people would be unlikely to use such a category in their induction. This argument, however, has two potential weaknesses. First, there was no precise specification of what makes categories conceptual and what exactly was missing from SKF stimuli (see, Sloutsky et al., 2007b). And second, if the categories were in fact arbitrary, why did adults rely on these categories when performing induction (see Gelman & Davidson, 2013, Experiment 1)?

Badger and Shapiro (2012) replicated the original Sloutsky et al. (2007a) procedure with two critical differences. First, they attempted to address the criticisms raised by Gelman and Waxman (2007) regarding the stimuli by using biologically plausible novel categories. Second, these researchers tested children from six different age groups, ranging from 3 to 9 years of age. Despite modifying the stimuli to address the criticisms applied to the stimuli used in SKF, Badger and Shapiro did not find that children relied on the category information when making inductive inferences across development. Instead, they observed a gradual transition from similarity-based to category-based induction between ages 3 and 9, with a majority of participants transitioning to making category-based inferences by 7 years of age. However, in the absence of a precise specification of what makes categories conceptual, one may still argue that the categories used by Badger and Shapiro (2012) also had insufficient conceptual grounding.

Recently, Gelman and Davidson (2013, hereafter GD) provided a more precise definition of what constitutes a conceptually-grounded category, and they identified a number of factors that may signal a relatively strong conceptual basis.

First, the **richness and interconnectedness** of shared features within a category are argued to be important. For example, members of an animate natural kind tend to share diet, habitat, vocalization, form of locomotion, form of reproduction, and perhaps many others. Thus, categories that differ in several of these signature dimensions will be conceptually rich, whereas categories that are not known to differ in any of these dimensions will be less so. Therefore, informing participants about these signature dimensions may be necessary for participants to construe the categories as conceptually distinct.

Second, GD suggested that the **nature of the distinguishing feature** can indicate whether categories are likely to be conceptually distinct. For example, categories that differ from one another according to inherent, functional features (such as the way of acquiring nutrients) are more distinct than categories that differ from one another according to arbitrary features (such as body stripes). And third, according to GD, the **level** at which categories differ from one another affects the conceptual distinctiveness of the categories: categories that differ at the ontological level (e.g., animal vs. artifact) are highly distinct, whereas categories that differ at the subordinate level (e.g., two kinds of dogs), or even at the basic level, are less so.

GD also formulated an important prediction: "...the conceptual account proposes that children are flexible in their inductive inferences, using perceptual similarity when categories have a weak conceptual basis, but using category membership for categories with a stronger conceptual basis" (p. 331). This prediction was tested in seven experiments with 4- and 5-year-olds and adults reported in GD. On the basis of these experiments, it was concluded that conceptual effects on induction exhibit an early onset: 4- and 5-year-olds exhibit category-based induction when categories have strong conceptual basis.

As we discuss in Section 1.3, several aspects of GD stimuli and procedures make it challenging to evaluate the conclusion that conceptual effects on induction exhibit an early onset. One goal of the present research is to re-examine this claim by addressing the limitations of the GD study. In doing so, the current research attempts to solve an important problem and contribute to our understanding of the development of inductive generalization. The second goal is to contribute to understanding of the development of conceptual effects on induction, with a particular focus on what changes, how and why.

To achieve the first goal, we take a closer look at GD, identify potential limitations in their approach, and conduct experiments addressing these limitations. Importantly, these experiments allow us to estimate the magnitude of conceptual effects on early induction. Then, to achieve the

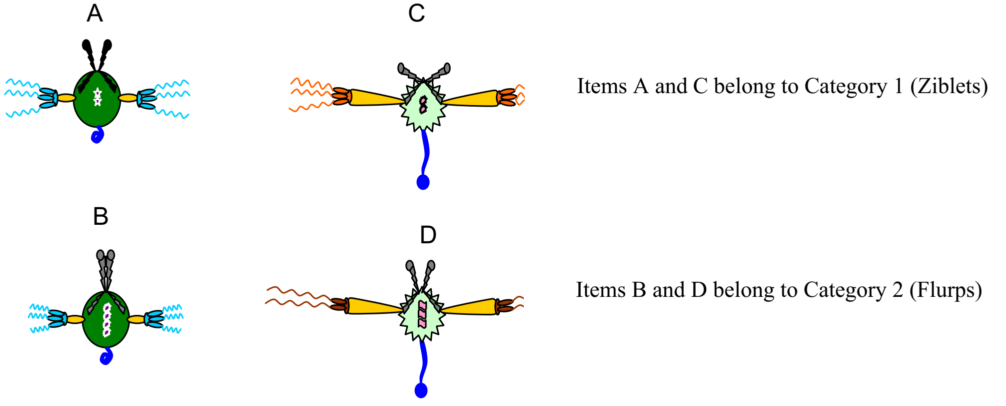

Fig. 1. Examples of stimuli in Sloutsky et al. (2007a). Category inclusion rule: ratio of wing fingers to body buttons. (A) A_1C_1, (B) A_1C_2, (C) A_2C_1, and (D) A_2C_2 ("A_1 and A_2" are two appearance prototypes and "C_1 and C_2" are two categories). Items A and C belong to Category 1 (Ziblets), and items B and D belong to Category 2 (Flurps).

second goal, we conduct several new experiments designed to measure the change in these effects in the course of development.

1.3. Taking a closer look at GD and estimating conceptual effects on induction

To achieve the first goal of the current research, we reexamine the GD research in greater detail. Before doing so, we first overview the overall logic and methodology of SKF.

1.3.1. Overview of SKF

SKF taught 4- and 5-year-old children two novel categories (ziblets and flurps), such that category membership was communicated by a rule and was independent of appearance similarity (see Fig. 1).[1]

Specifically, the two categories could be distinguished based on the ratio of wing fingers to body buttons: ziblets had more wing fingers than body buttons, whereas flurps had more body buttons than wing fingers. As shown in Fig. 1, whereas the rule was a perfect predictor of category membership, the appearance was not predictive: ziblets were just as similar to flurps as they were to other ziblets; likewise, flurps were as similar to ziblets as they were to other flurps.

Upon learning the categories, children were presented with a match-to-sample induction task, designed to examine whether their inductive inferences were driven by category membership or by appearance similarity. To achieve that, perceptual similarity was put in direct conflict with category membership (see Fig. 2). As shown in the figure, the target item and the item on the bottom left belong to the same category (but differ in appearance), whereas the target item and the item on the bottom right have similar appearances (but belong to different categories). Critically, SKF used a relational rule (i.e., "has more fingers than body buttons") rather than a simpler featural rule (e.g., "has red feet") to eliminate the possibility that participants perform induction by simply matching the rule feature.

Furthermore, although the categories were labeled during category learning phase, no labels were introduced during induction testing. This was done to eliminate the possibility of performing induction by merely matching labels. In sum, the design used in SKF allowed them to test whether children use category membership or appearances similarity as a guide in their induction.

Using this approach (and introducing a number of important controls), SKF found that young children used perceptual similarity rather than category membership to guide their inductive inferences (see also Badger & Shapiro, 2012). On the basis of these findings SKF concluded that (1) when inferring hidden properties, young children relied on appearance similarity (rather than on a common natural-kind category) and (2) early induction is similarity based and not category based.

[1] Figures 1–4 appear in color in the online version of the paper.

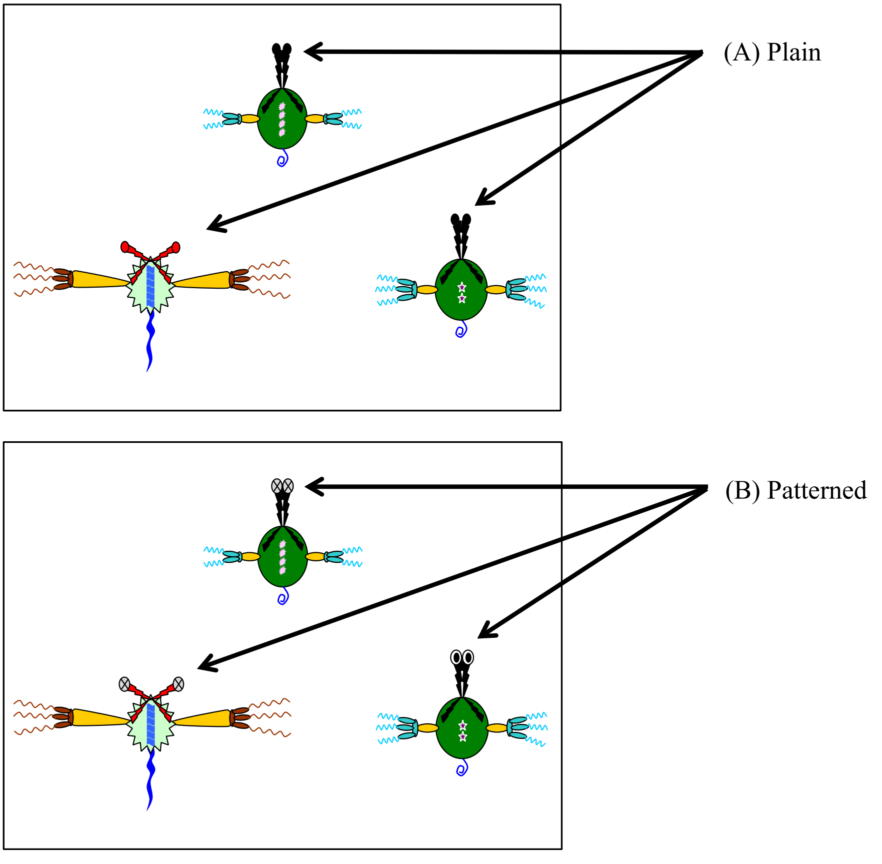

Fig. 2. (A) Sample picture set (used in SKF and GD Experiment 1). (B) Sample modified picture set (used in GD Experiments 2–7). In both 2A and 2B, the top item and the item on the bottom left are flurps, whereas the item on the bottom right is a ziblet. Note that some features in Fig. 2a are plain, whereas these features in Fig. 2b are patterned (these features are marked by arrows). Reasons for this distinction are explained in the text.

However, as argued by GD, "it is premature to conclude that early induction is based on perceptual similarity across the board" (p. 330). GD (as well as, Gelman & Waxman, 2007) noted several aspects of SKF that might limit or reduce children's reliance on category information and conversely encourage the use of perceptual features. Their primary concern was that the novel categories used by SKF were not natural kinds and they were not conceptually-based (but see Sloutsky et al., 2007b). The concern is potentially important because the knowledge-based account "predicts that natural kinds will serve as a guide for children's inferences, but that categories that are not natural kinds will not serve that purpose" (p. 330). Although Badger and Shapiro (2012) replicated SKF with arguably conceptually distinct categories, the goal of GD was to address this concern more systematically.

1.3.2. Overview of GD

In an attempt to do so, GD introduced a number of modifications to SKF original stimuli and procedures. First, they attempted to ascertain the categories used were indeed conceptually-based. Specifically, GD (1) changed the level at which categories differed from one another (at least one experiment introduced the highest level of distinction by introducing ontologically distinct kinds – animals vs. machines); (2) increased the richness of shared features within a category; and (3) changed the nature of the distinguishing feature by making sure that categories differed from one another according to inherent, functional features.

In addition to making sure that the categories were indeed conceptually-based, GD introduced a number of other modifications. Although not all these modifications are equally important, for purposes of replication it is necessary to keep track of all of them.

Most importantly, GD modified the nature of the rule: whereas SKF used a relational rule (i.e., button-to-finger ratio), GD introduced a featural rule (i.e., type of pattern on antennae, introduced as eyes vs. bolts). In our view, this modification is potentially of critical importance. The entire premise of SKF was to use a relational rule to prevent induction based on simple feature matching. In fact, there is evidence that if a feature is sufficiently salient (Deng & Sloutsky, 2012) or attention is attracted to a feature (Deng & Sloutsky, 2015), 4- and 5-year-olds will rely on this feature in their induction and categorization. Furthermore, they do so, even if the feature is in conflict with category information (Deng & Sloutsky, 2012, 2013). Therefore, in GD induction could be performed on the basis of feature matching (rather than accessing a common category), something that could not be done in the original SKF paradigm.

In addition, GD introduced category contrast, emphasizing how the two categories differed from one another, which could have helped shifting attention to the category-defining feature. GD also made a number of less important appearance and procedural modifications (see Table 1 for a full list of differences).

Not all of the modifications presented in Table 1 are conceptual in nature: For example, Differences 5–7 can be applied to any stimulus set and affect how stimuli are processed, without making the stimuli conceptually grounded or communicating what these stimuli are. Take any non-conceptual category, such as circles or rectangles. With respect to Difference 6, circles and rectangles can be grouped on the basis of a relation, such as aspect ratio (e.g., tall and narrow objects vs. short and wide objects), or on the basis of a feature, such as color (e.g., red vs. blue). Similarly, with respect to Difference 7, circles and rectangles could be introduced either without a contrast or could be contrasted (e.g., "this is a red circle, it goes over here, and this is a blue circle, it goes over there"), with the contrast distinguishing the two categories. Finally, Difference 5 (which is arguably a minor one) can also be applied to any of these stimulus sets: circles could be patterned or plain. As we explain below, we identify these differences as "attentional". Finally, there were a number of procedural modifications (Differences 8–11).

As suggested in Table 1, the differences between SKF and GD could be roughly divided into three classes: conceptual, attentional, and procedural. "Conceptual" are the differences that may potentially make categories more conceptually grounded, without changing the nature of the stimuli. "Attentional" are the differences in stimuli or procedure that could make it easier to attend to the category-relevant distinction, without making the distinction conceptually-based. "Procedural" are the differences that could streamline the procedure. They were unlikely to generate patterns of responses that could be interpreted as category-based induction in GD's experiments because they

Table 1
Methodological differences between SKF (Sloutsky et al., 2007a) and GD (Gelman & Davidson, 2013).

		SKF	GD
Conceptual differences			
1	C1: Category level	Basic level	Ontological level
2	C2: Distinguishing feature	Less functional	More functional
3	C3: Associated features	Less interconnected	More interconnected
4	C4: Description of habitat	No	Yes
Attentional differences			
5	A1: Feature shading	Plain	Patterned
6	A2: Category rule	Relational	Featural
7	A3: Category Contrast	Absent	Present
Procedural differences			
8	P1: Response picture cue	Present	Absent
9	P2: Streamlined wording	No	Yes
10	P3: Character name	Fritz	Mike
11	P4: Reference to another planet	Yes	No

Table 2
Conceptual and attentional factors across experiments in GD.

	Conceptual	Attentional	% Category-Based Induction	Notes
Experiment 1	None	None	27.5[*]	Replication of SKF
Experiment 2	C1–C4	A1–A3	78[*]	Target experiment
Experiment 3	C1–C4[a]	A1–A3	67.8[*]	Target experiment
Experiment 4	C1–C4[b]	A1–A3	65.7[+]	Target experiment
Experiment 5	None	A1	27[*]	Control experiment
Experiment 6	None	A1, A3[c]	33.3[*]	Control experiment
Experiment 7	None	A1, A2	46.3	Control experiment

[a] In contrast to Experiment 1–2, this experiment used unfamiliar words for to-be-generalized properties (e.g., "sticky toma inside").
[b] In contrast to Experiments 2–3, used basic-level, instead of ontological distinction.
[c] Used an impoverished picture cue.
[*] Significantly different from chance.
[+] Non-significant trend.

appeared in both the target experiments (that generated these patterns) and control experiments (that did not generate these patterns).

GD argued that children made category-based inferences in their version of the task because of the *conceptual* modifications GD introduced. However, it is possible that non-conceptual modifications played the crucial role in children's tendency to select category matches by making the category-relevant distinction more salient and thus more likely to be attended to. In other words, it is possible that GD's findings stemmed from their non-conceptual rather than their conceptual manipulations.

In particular, the "attentional" modifications could generate the differences: as shown in Table 2, in all target experiments reported by GD the attentional modifications were introduced, whereas none of the control experiments had all attentional modifications. As a result, GD's design does not allow distinguishing between the contribution of conceptual and attentional factors. Therefore, their findings leave three distinct possibilities on the table. First, it is possible that category-based induction (whenever found) in GD was driven solely by attentional factors. For example, Deng and Sloutsky (2015) recently demonstrated that attracting children's attention to a particular feature during category learning has a powerful effect on how children used this feature in their categorization responses. Second, it is possible that category-based induction in GD was driven by conceptual factors, the possibility favored by GD. And third, it is possible that category-based induction was driven by a combination of attentional and conceptual factors.

1.4. Present research

One of the goals of our research is to re-examine the mechanism of early induction and estimate the contribution of conceptual and attentional factors. To achieve this goal, we took the following approach. Recall that GD introduced four conceptual modifications, three attentional modifications, and four procedural modifications (see Table 1). Therefore, an estimation of an independent contribution of each of these modifications (or their interactions) would require a $4 \times 3 \times 4$ design, with a total of 48 groups. Given our goal of estimating the contribution of conceptual and attentional factors, we simplify the problem in the following ways. First, in all reported experiments, we adopt all the procedural modifications introduced by GD. Therefore, any differences between the current results and GD cannot stem from the procedural differences. And second, we treat conceptual and attentional modifications introduced by GD as groups, by varying all conceptual ones together and all attentional ones together.

Although we disagree with GD that SKF used non-conceptual categories,[2] for the sake of the argument, we will assume here that SKF's categories were arbitrary. Also SKF did not use any of the attentional modifications introduced by GD. We therefore consider SKF and GD's Experiment 1 (which

[2] For example, in the Control Experiment described in SKF's Experiment 1, children were told that ziblets had more wing fingers than body buttons because they used fingers to catch food (similarly, a conceptual reason was given for the flurps' category rule).

is a replication of SKF) as approximations of a baseline that does not have any of the attentional or conceptual factors. We denote this baseline as C−A− (where "C" stands for all conceptual factors introduced by GD and "A" stands for all attentional factors). In contrast, GD's Experiment 2 had both conceptual and attentional factors, and we denote it as C+A+. Therefore, to have a fully crossed design, we needed (1) a condition that has all the conceptual factors used by GD, but none of the attentional factors (i.e., the C+A− condition) and (2) a condition that has all attentional factors used by GD, but none of the conceptual factors (i.e., the C−A+ condition).

To achieve the goal of estimating the effects of conceptual and attentional factors on early induction, we conducted three experiments with 4- and 5-year-olds and adults. In Experiment 1, we introduced all the attentional modifications introduced by GD, but none of the conceptual ones (i.e., the C−A+ condition). In contrast, in Experiment 2, we introduced all the conceptual modifications introduced by GD, but none of the attentional ones (i.e., the C+A− condition). In Experiment 3, we replicated this approach with basic-level rather than ontological distinctions (cf. GD's Experiment 4). We then used all the conditions combined (i.e., C+A+, C+A−, C−A+, and C−A−) to estimate an independent or interactive contribution of each factor.

The second goal of the present research was to gain a better understanding of development of category-based induction. To achieve this goal, we replicated the C−A− condition and the C+A− condition with 7-year-olds. These data, in conjunction with data with 4- and 5-year-olds, allow us to estimate developmental changes in the conceptual contributions to induction, thus resulting in a better understanding of the development of category-based induction.

1.4.1. Overview of the paradigm

The reported study consisted of five experiments, all based on SKF's original design and GD's modifications and one control experiment (Experiment 2A). Specifically, as mentioned earlier, in the five experiments we preserved all the procedural modifications introduced by GD in all experiments reported here. At the same time, we varied orthogonally the conceptual and attentional factors introduced by GD.

Similar to SKF and GD, the basic task of all experiments consisted of five phases: category training, category learning, initial categorization, induction, and final categorization. During the category training phase, participants were presented with descriptions of the two to-be-learned categories. They were also given a rule that distinguished the two categories. Then the category learning phase started: participants were presented with creatures and asked to predict the category of each item. After each response, participants were provided with corrective feedback and reminded of the category rule. The initial categorization phase was similar to the category learning phase, except that participants were asked to categorize items that were not used during category learning and no feedback was provided. During the induction phase, participants were presented with a triad induction task. Each triad consisted of a target and two test items, with one test item matching the target on category membership but not the appearance, and the other test item matching the target on appearance but not the category membership. On each trial, participants learned a property of the target item and were asked to generalize this property to one of the test items. No feedback was provided. The final categorization phase was identical to the initial categorization task, except that the items were a subset of the test items used in the induction task.

There were two sets of predictions, one pertaining to the two theoretical proposals on early induction, and the other pertaining to conceptual influences on category-based induction in children. First, if participants perform category-based induction, then they should rely on category membership and generalize the target properties to the item that belongs to the same category as the target. In contrast, if participants perform similarity-based induction, then they should rely on appearance information and generalize the target properties to the item that looks like the target, despite their knowledge of category membership. Second, if it is the conceptual basis of categories that leads to category-based induction in children, then children (1) should rely on category membership when conceptual information is present (even in the absence of attentional factors) and (2) should not rely on category membership when conceptual information is not presented (even in the presence of attentional factors). Conversely, if attentional factors contribute to category-based induction in children, then children should rely on (1) category membership when attentional factors are present and (2) appearance information when attentional factors are absent.

2. Experiment 1: The role of attentional factors in early induction

The goal of Experiment 1 was to directly examine the effect of attentional factors on category-based induction in the absence of conceptual factors. This experiment was a variant of GD's Experiment 4. Similar to GD, we used all the attentional modifications introduced by GD but in contrast to GD, none of the conceptual modifications were introduced, which resulted in the C−A+ condition. If it is the conceptual basis of categories that leads to the pattern of induction reported by GD, then children in this experiment should rely on appearance similarity rather than on the category rule. However, if attentional factors contributed to the pattern reported by GD, then children in this experiment should rely on the category rule in their induction.

2.1. Method

2.1.1. Participants

Twenty-four preschool-age children (M = 4.58 years, SD = 0.31 years, range = 3.99 to 5.16 years; 13 girls) and twenty-four adults (M = 19.09 years, SD = 0.92 years, 17 women) participated in this experiment. Three additional children were tested but excluded from the sample because they failed to learn the category (see *Design and procedure*). In this and all other experiments reported here, children were recruited from childcare centers and preschools located in middle-class suburbs of Columbus, Ohio. Adults were undergraduate students at The Ohio State University, participating for course credit. Also, in all experiments, children were tested by an experimenter in a quiet room in their childcare center or preschool, and adults were tested in a quiet room in the laboratory on campus.

2.1.2. Materials

Materials were similar to those used previously by GD and consisted of: a drawing of a boy named Mike, colorful drawings of bug-like creatures (see Fig. 3), a drawing of a tree and a drawing of a desert that served as response cues (see Fig. 4A).

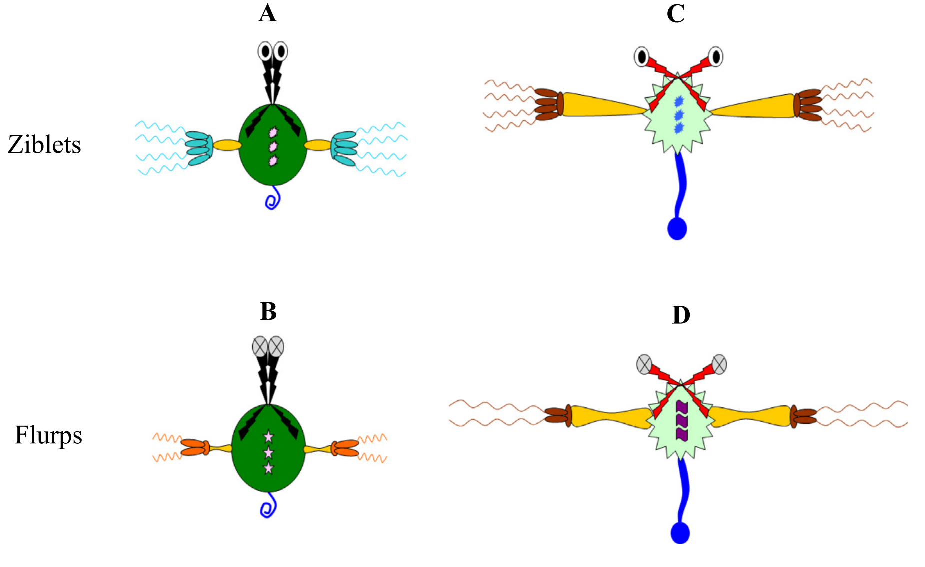

Fig. 3. Examples of the stimuli used in Experiment 1: (A) A_1C_1, (B) A_1C_2, (C) A_2C_1, and (D) A_2C_2. Items A and C belong to Category 1 (C_1 = Ziblets), and items B and D belong to Category 2 (C_2 = Flurps).

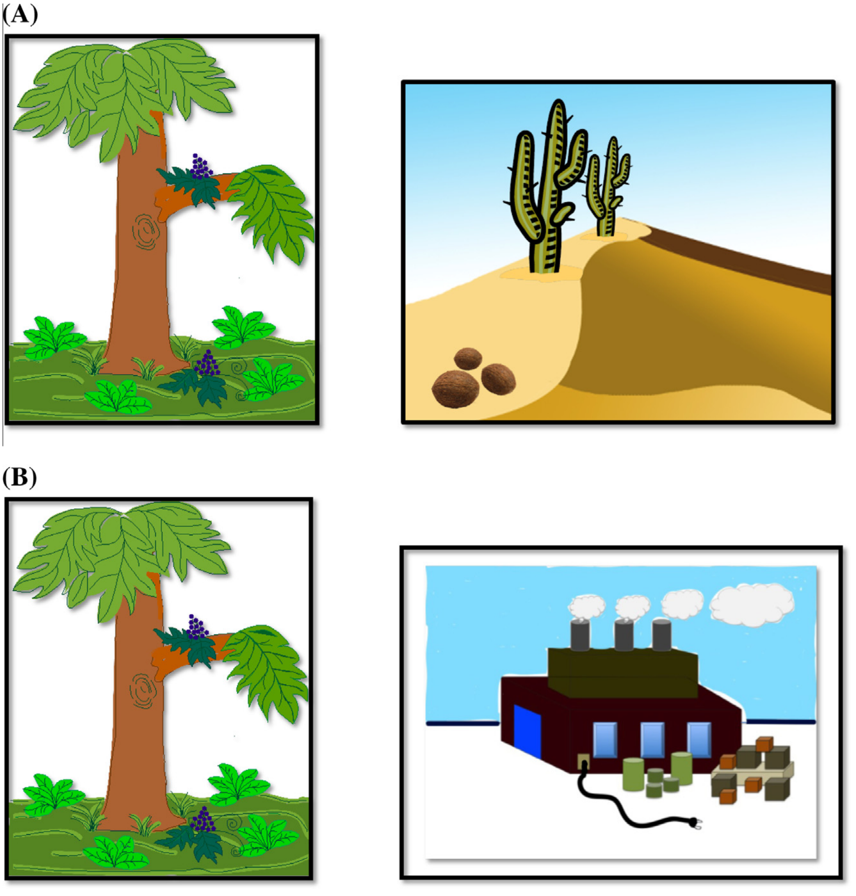

Fig. 4. Response cues. (A) Pictures of tree and desert used in Experiments 1, 3, and 5. (B) Pictures of tree and factory used in Experiment 2. We thank Susan Gelman and Natalie Davidson for providing these pictures.

There were two categories contrasting at a basic level, and the creatures of each category were accompanied by the novel label *ziblet* or *flurp*. The category structure was identical to that used by GD, with the exemplar of each category having seven features. Six of their features—body, tail, wings, buttons, fingers and antennae—were probabilistic and they jointly reflected two types of appearance, A_1 and A_2, respectively. One feature (i.e., the marks on the antennae) was deterministic and it perfectly separated the two categories. This feature was used to identify two types of category membership, C_1 and C_2, respectively. Similar to GD, we used this feature as the category rule.

At the same time, we introduced a number of critical differences in order to eliminate conceptual information, while retaining attentional information. First, unlike GD where the marks were introduced as eyes for ziblets and bolts for flurps in target Experiments 2–3, we introduced the marks as round teeth for ziblets and sharp teeth for flurps (which was similar to control Experiments 4–6 in GD). According to GD, such a difference is not conceptually distinct. And more importantly, unlike GD where the marks were introduced in a conceptual context and were biologically meaningful, we excluded all conceptual information used by GD. The following descriptions were given to participants:

Here is a Ziblet. Can you say Ziblet? ....Good! Ziblets have round teeth. See? Here are round teeth. Can you point to its round teeth? Good, those are its round teeth. All Ziblets have round teeth.

Now, here is a Flurp. Can you say Flurp? . . ..Good! Flurps have sharp teeth. See? Here are sharp teeth. Can you point to its sharp teeth? Good, those are its sharp teeth. All Flurps have sharp teeth.

Overall, four types of items were created: A_1C_1 and A_2C_1 items (i.e., stimuli that were members of Category 1 (C_1), with either A_1 or A_2 appearance) and A_1C_2 and A_2C_2 items (i.e., stimuli that were members of Category 2 (C_2), with either A_1 or A_2 appearance). Fig. 3 shows an example of each type of stimuli.

The response cues (i.e., drawings of tree and desert associated with ziblets and flurps, respectively) were identical to those in GD, with one critical difference. Unlike GD's Experiment 4 where these drawings they were introduced in a rich conceptual contexts referring to different diet and habitat of ziblets and flurps, we referred the drawings as pictures that ziblets and flurps liked (with ziblets liking tree pictures and flurps liking the desert pictures or vice versa).

2.1.3. Design and procedure

In this and all other experiments reported here, the procedure consisted of five phases: category training, category learning, initial categorization, induction, and final categorization. The procedures were similar for both adults and children, and for both age groups the experiment was presented on the computer and controlled by E-prime software (Version 2.0; Schneider, Eschman, & Zuccolotto, 2002).

There were minor differences between children's and adults' procedures pertaining to the way the instructions were presented, the questions were asked, and the responses were recorded. Adults read the instructions and questions on the computer screen and pressed the keyboard to make responses, whereas for children, a trained experimenter presented instructions and the questions verbally and recorded children's responses by pressing the keyboard. The experiment took approximately 6 min for adults and approximately 10 min for children.

2.1.3.1. Category training. This phase was similar to that of GD's Experiment 4, except that all conceptual information about categories introduced by GD was removed. Participants were presented with a character, named Mike, who was learning about two kinds of creatures. To help Mike, participants were asked to determine whether each creature was a ziblet or a flurp. The following cover story was given to the participants:

This is Mike. He just moved to a new country called Elbee with his family. Everything in Elbee is different from where he used to live. Mike is beginning to learn about all the things in Elbee. His new teacher is helping him. Mike's new teacher says that things in Elbee sometimes look a lot alike. So she's helping Mike learn how to tell them apart. She showed him some things called ziblets and some things called flurps. She says that ziblets and flurps are two different kinds of things that look a lot alike. Now I'm going to show you some of them.

Then participants were presented with an exemplar of a ziblet, followed by an exemplar of a flurp, with the experimenter explaining the category rule (all ziblets have round teeth, whereas all flurps have sharp teeth) while pointing to the distinguishing feature. Similar to GD's Experiment 4, two associated pictures (i.e., tree, desert) were used as response cues. Participants saw the tree picture and a ziblet (or the desert picture and a flurps) side by side, and were told: "All ziblets (or flurps) like this picture." Similar to GD, the category training phase emphasized the contrast between two categories by presenting a ziblet and a flurp together while pointing out the category rule that distinguished the two categories.

2.1.3.2. Category learning. Participants were presented with eight trials, in which they were asked to determine the category of the items. Similar to GD, there were two response options for the participants. They could respond by either identifying whether a creature was a ziblet or a flurp, or by pointing to one of the two response cues (introduced in this experiment as pictures the creature liked). After responding, they received corrective feedback and were reminded of the rule (i.e., the teeth) for determining category membership. Participants were presented with A_1C_1, A_1C_2, A_2C_1, and A_2C_2

items (two training trials per item type, in a random order), so that only the rule was predictive of category membership.

2.1.3.3. Initial categorization. This phase was identical to the category learning phase except for two differences. First, participants were presented with new A_1C_1, A_1C_2, A_2C_1, and A_2C_2 items (two trials per item type, with a total of eight trials, in a random order). And second, no feedback was provided and the experimenter did not repeat the category rule. To be included in the sample, participants had to perform correctly on at least six of the eight trials (i.e., respond with at least 75% accuracy). Three children were excluded because they did not reach this criterion.

2.1.3.4. Induction. The induction task was administered immediately after the initial categorization phase and it was introduced by telling the participants to answer some questions about the creatures. There were 12 trials presented in a random order. On each trial, participants were shown a triad consisting of a target item and two test items (neither the target nor the test items were shown in the first three phases). The assignment of item type was identical to GD's design. For a subset of participants, the target was an A_1C_1 item and the two test items were A_1C_2 and A_2C_1 items; and for the rest of the participants, the target was an A_1C_2 item and the two test items were A_1C_1 and A_2C_2 items. The left-right position of the test items was counterbalanced across trials. On each trial, participants were told about a hidden property of the target and asked to choose the test item that had the same hidden property. The properties used in induction were the same ones as used by GD and were familiar to children (e.g., has a spine in its back).

Category labels were not given during induction, and all items were referred to as "this one". Notice that each induction triad enabled us to directly pit appearance against category membership. The proportion of responses that were based on the category rule was the dependent variable. Therefore, reliance on the rule will result in above chance values, whereas reliance on appearance with result in below chance levels.

2.1.3.5. Final categorization. After the induction task, all participants were presented with a final categorization task. This task was similar to the initial categorization task, except that the items were the ones used as the test items in induction. The final categorization task was included to ascertain that participants did not forget the category rule in the course of experiment and could correctly categorize the induction items.

As a reminder, the design of this experiment enabled a direct examination of the effect of attentional factors on category-based induction in the absence of conceptual factors. If it is the conceptual basis of categories that leads to category-based induction in children, as claimed by GD, then children in this experiment should rely on appearance similarity rather than on the category rule. However, if attentional factors contributed to children's reliance on the category rule reported by GD, then children in this experiment should also rely on the category rule in their induction.

2.2. Results and discussion

The overall results of this experiment are presented in Fig. 5. Preliminary analyses focused on whether participants learned the categories and remembered the category rule over the course of experiment. Participants who passed the categorization criterion were highly accurate in the initial categorization task, $M = 0.95$ for children and $M = 0.98$ for adults, both greater than chance, $ps < .001$, $ds > 5.0$. Their performance remained highly accurate in the final categorization task, $M = 0.85$ for children[3] and $M = 0.98$ for adults, both greater than chance, $ps < .001$, $ds > 1.8$.

The primary analyses focused on the comparison of the performance in induction between children and adults (see Fig. 5). These data were analyzed with an independent-sample t-test, and the proportion of category-based responses of children was compared with that of adults. As predicted,

[3] In Experiment 1, children's accuracy in the final categorization task was somewhat lower than that in the initial categorization task, $t(23) = 2.36$, $p = .027$, $d = 0.65$. In all other experiments reported here, children's accuracy did not differ between the initial and final categorization tasks, $ps > .090$, $ds < 0.41$.

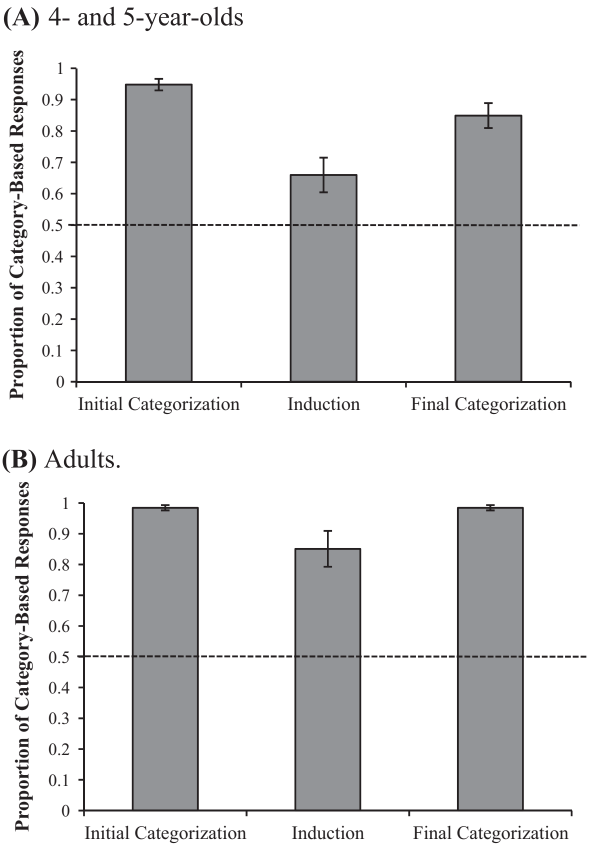

Fig. 5. Proportion of category-based responses in the categorization and induction tasks of Experiment 1. The chance level is 0.5. Error bars represent standard errors of mean.

adults provided more category-based responses than children, $t(46) = 2.38$, $p = .022$, $d = 0.68$. More importantly, similar to adults who relied on category information in the induction task ($M = 0.85$, above chance, $p < .001$, $d = 1.2$), children also relied on category information in the absence of conceptual information about categories, $M = 0.66$, above chance, $p = .008$, $d = 0.6$ (cf. with $M = 0.657$ reported by in GD's in Experiment 4, see Table 2).

The results replicate central findings of GD's Experiment 4, however, in contrast to GD's Experiment 4, where both conceptual and attentional factors were present, only attentional factors were present in our Experiment 1. These findings suggest that, when attention is attracted to the category rule, young children can rely on this rule (cf. Deng & Sloutsky, 2015) and they do not need conceptual information to do so. In addition, these findings suggest that the attentional factors introduced by GD are sufficient to account for the differences between GD and SKF. Therefore, it is possible that conceptual information played little or no role in the pattern of induction observed by GD.

Alternatively, it is possible that, whereas conceptual information is not necessary for category-based induction in young children, it is sufficient. It is also possible that conceptual and attentional factors interact, thus jointly contributing to children's reliance on the category rule observed by GD. To examine these possibilities, we needed to examine the contribution of conceptual factors when attentional factors were not present by running the C+A– condition. This was done Experiments 2–3.

Specifically, in Experiment 2, we introduced all the conceptual factors used by GD, but none of the attentional ones. We further extended this approach in Experiment 3 to basic-level rather than ontological distinctions. We then used previous and current data to examine effects of all possible combinations of attentional and conceptual factors (i.e., C+A+, C+A−, C−A+, and C−A−) to conduct statistical analyses and estimating the contribution of attentional and conceptual factors to induction.

3. Experiment 2: The role of conceptual factors in early induction

The goal of Experiment 2 was to directly examine the effect of conceptual factors on induction in the absence of attentional factors by creating the C+A− condition. If the conceptual basis of categories children's reliance on the category rule observed by GD, then children in this experiment should also rely on the category rule. In contrast, if attentional factors contributed to the pattern observed by GD, then children in this experiment should not rely on the category rule in their induction.

3.1. Method

3.1.1. Participants

Twenty-four preschool-age children (M = 4.64 years, SD = 0.45 years, range = 4.02 to 5.38 years; 13 girls) and twenty-four adults (M = 19.46 years, SD = 1.27 years, 12 women) participated in this experiment. Six additional children and one additional adult were tested but excluded from the sample because they failed to learn the category.

3.1.2. Materials

Recall that our goal was to create a C+A− condition and we needed to eliminate all attentional factors introduced by GD (A1–A3 in Table 1), while retaining conceptual factors. To achieve this goal, we introduced the following changes to the materials used in Experiment 1: we changed the category rule, eliminated the category contrast, and replaced patterned antennae with plain ones (see Fig. 2).

The category rule in Experiment 2 was exactly the same as in the SKF's original design (and GD' Experiment 1): the relation between the number of body buttons and the number of fingers. Specifically, creatures of one category (C_1 stimuli) had more fingers than buttons, whereas creatures of the contrasting category (C_2 stimuli) had more buttons than fingers. This category rule, compared to that in Experiment 1, was far less apparent (i.e., participants had to compare the number of fingers and the number of buttons) and thus provided much less attentional support for identifying category membership.

In addition, to add conceptual factors, we used all conceptual information that was introduced by GD's Experiment 2 (see C1–C4 in Table 1). First, the two categories contrasted at an ontological level coming from two ontologically distinct domains, with ziblets being a type of animal and flurps being a type of artifact (i.e., C1). Accordingly, they differed on multiple properties associated with these distinct kinds, such as diet and habitat (i.e., C3). Similar to GD's Experiment 2, they were introduced as kind-based distinctions: specifically, ziblets were introduced as living in trees and eating grapes, whereas flurps were introduced as coming from factories and using electricity. The response cues were drawings of tree and factory (see Fig. 4B), and rich conceptual contexts (identical to that in GD) were provided (i.e., C4). And finally, rich conceptual information about the category rule was provided (i.e., C2). Specifically, ziblets had more fingers than buttons so they could use fingers to climb and get grapes, whereas flurps had more buttons than fingers because buttons kept flurps together.

The following wording was used to introduce the categories:

Here is a Ziblet. Can you say Ziblet? . . . Good! Look at its buttons. How many buttons does this ziblet have? . . . That's right, there are two buttons. Look at its fingers on one wing. How many fingers? . . . That's right, there are three. Are there more fingers or more buttons? . . . Yes, there are more fingers. Remember, ziblets always have more fingers than buttons. Do you know why ziblets have more fingers than buttons? Ziblets have more fingers so they can climb. [click to show the tree picture] Look at this picture! Ziblets eat grapes and live in trees, like this one. Ziblets have more fingers than buttons so they can climb. What do ziblets eat? . . . That's right, they eat grapes. Where do ziblets live? ... That's right, they live in trees.

Now, here is a Flurp. Can you say Flurp? . . ..Good! Look at its buttons. How many buttons does this Flurp have? . . . That's right, there are six buttons. Look at its fingers on one wing. How many fingers? . . . That's right, there are four. Are there more fingers or more buttons? . . . Yes, there are more buttons. Remember, flurps always have more buttons than fingers. Do you know why flurps have more buttons than fingers? Flurps have more buttons to keep them together. [click to show the factory picture] Look at this picture! Flurps use electricity and come from factories, like this one. Flurps have more buttons than fingers to keep them together. What do flurps use? . . . That's right, they use electricity. Where do flurps come from? . . . That's right, they come from factories.

3.1.3. Design and procedure

The design and procedure were similar to those of Experiment 1, with one critical difference. In contrast to Experiment 1 (and all target experiments in GD), where the contrast between the two categories was emphasized by presenting a ziblet and a flurp together and pointing out the category rule for determining category membership (i.e., A3), no category contrast was used in Experiment 2.

As a reminder, this design enabled a direct examination of the effect of conceptual factors on category-based induction in the absence of attentional factors. If it is the conceptual basis of categories that leads to children's reliance on the category rule reported by GD, then children in this experiment should also rely on the category rule. However, if, as evidenced by Experiment 1 above, attentional factors contributed to children's category-based induction reported by GD, then children in this experiment should rely on appearance in their induction.

3.2. Results and discussion

The results are presented in Fig. 6. Similar to Experiment 1, the preliminary analyses focused on whether participants learned the categories and remembered the category rule over the course of experiment. Participants who passed the categorization criterion were highly accurate in the initial categorization task, $M = 0.91$ for children and $M = 0.99$ for adults, both greater than chance, $ps < .001$, $ds > 4.4$. Their performance remained highly accurate in the final categorization task, $M = 0.87$ for children and $M = 0.99$ for adults, both greater than chance, $ps < .001$, $ds > 3.9$.

The primary analyses focused on the comparison of the induction performance between children and adults (see Fig. 6). As predicted, adults provided more category-based responses than children, $t(46) = 10.84$, $p < .001$, $d = 3.13$. More importantly, in contrast to Experiment 1 where children exhibited similar pattern of performance in the induction task as adults, in Experiment 2 children differed from adults. Specifically, unlike adults who relied on category information, $M = 0.93$, above chance, $p < .001$, $d = 2.2$, children ignored category information, relying instead on appearance information even in the presence of conceptual information about categories, $M = 0.27$, below chance, $p < .001$, $d = 1.0$.

Therefore, despite the fact that conceptual information was provided, children relied on appearance similarity and not on category information. These findings are in a sharp contrast with the results of GD's Experiment 2. Recall that in GD's Experiment 2, children provided predominately category-based responses ($M_{\text{category-based}} = .78$), whereas in the current experiment children provided predominantly similarity-based responses ($M_{\text{category-based}} = .27$). The fact that all the conceptual factors introduced by GD were retained in the current experiment suggests that these factors have little to no effect on the pattern of induction.

Results of Experiment 2 indicate that when attentional factors are not present, children, unlike adults who reliably use category membership in induction, tend to make inductive inferences on the basis of appearance, even when a rich conceptual basis is presented. These results provide evidence against GD's argument about the conceptual influences on category-based induction in children and suggest that early induction is similarity-based.

Although these results provide evidence for similarity-based induction, it could be argued that children's reliance on similarity rather than on category information in Experiment 2 (as well as in SKF) stems from elevated task demands: whereas children can perform categorization with a relational rule, somewhat higher task demands of induction may prevent them from doing so. To address this issue, we conducted an additional control experiment (Experiment 2A) with 4- and 5-year-olds

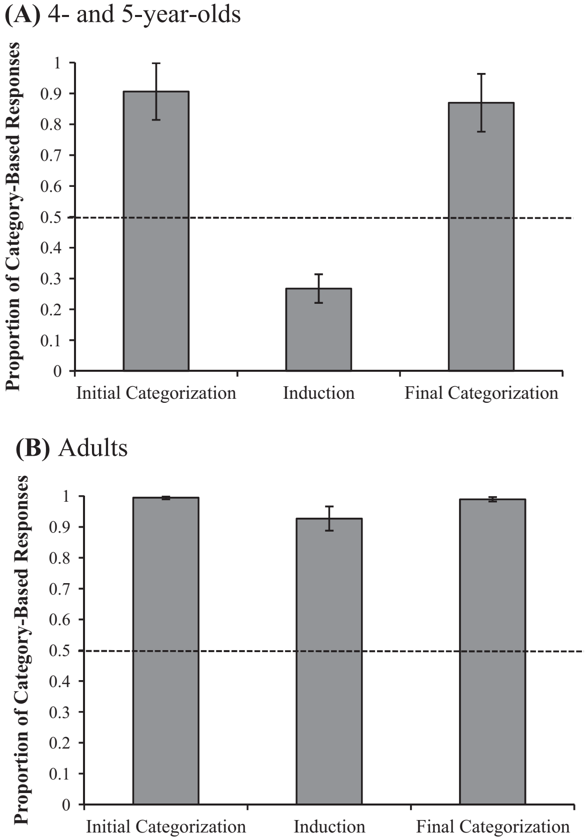

Fig. 6. Proportion of category-based responses in the categorization and induction tasks in Experiment 2. The chance level is 0.5. Error bars represent standard errors of mean.

($N = 15$, $M_{age} = 4.9$ years, $SD = 0.2$ years, 8 girls). In Experiment 2A, we trained children to perform induction rather than categorization. The stimuli (the triads and to-be-inferred properties) were identical to those used in the induction phase of Experiment 2. Given the control nature of this experiment, no conceptual information was provided.

During training, participants learned to use the same relational rule as in Experiment 2 (as well as in the rest of the experiments reported here, SKF experiments, and Experiment 1 of GD) and told that animals that have more fingers than buttons also have the same stuff inside. Similar to the category learning procedure, there were eight training trials and participants' responses were accompanied with corrective feedback. They were then presented with eight test induction trials, with no feedback provided at testing.

Results indicated exceedingly high induction accuracy ($M = .92$, above chance, $p < .001$), which was comparable with that of children who learned categories based on the relational rule ($M = .91$ in Experiment 2, $M = .89$ in Experiment 3, $M = .95$ in Experiment 1 of SKF, and $M = .93$ in Experiment 1 of GD; *Grand Average* = .92). Therefore, there is no evidence that the failure of category-based induction with a relational rule stems from elevated task demands.

4. Experiment 3: The conceptual factors with the basic-level distinction

Note that according to the knowledge-based approach, broad ontological distinctions (such as a distinction between a natural kind and an artifact) are presumed to be the most compelling. Although young children did not rely on conceptual information when provided with such broad ontological distinction in Experiment 2, it is still possible that an ontological distinction offers some advantage, compared to a less compelling distinction between basic-level categories. In Experiment 3, we addressed this question by replicating Experiment 2 with basic-level categories.

4.1. Method

4.1.1. Participants

Twenty-four preschool-age children (M = 4.68 years, SD = 0.40 years, range = 4.00–5.54 years; 15 girls) and twenty-four adults (M = 19.49 years, SD = 0.97 years, 12 women) participated in this experiment. Six additional children and five additional adults were tested but excluded from the sample because they failed to learn the category.

4.1.2. Materials

Materials were similar to those of Experiment 2, with three important differences. First, the two categories differed at a basic level rather than an ontological level, with ziblets and flurps being introduced as two types of creatures. Second, the associated response cues (i.e., drawings of tree and desert) were introduced as the habitats for ziblets and flurps respectively. And third, the descriptions about the category rule changed accordingly. Specifically, participants were told that ziblets had more fingers than buttons so they could use their fingers to climb and get grapes, whereas flurps had more buttons than fingers because their buttons were sticky and they used their sticky buttons to catch insects. Given that only conceptual factors were present (whereas attentional were absent), this condition, similarly to Experiment 2, is a C+A− one.

4.1.3. Design and procedure

The design and procedure were identical to that of Experiment 2 except for the information provided about how ziblets and flurps differed, as described above.

4.2. Results and discussion

The overall results are presented in Fig. 7. Similar to Experiments 1–2, the preliminary analyses focused on whether participants learned the categories and remembered the category rule over the course of experiment. Participants who passed the categorization criterion were highly accurate in the initial categorization task, $M = 0.89$ for children and $M = 0.95$ for adults, both greater than chance, $ps < .001$, $ds > 3.7$. Their performance remained highly accurate in the final categorization task, $M = 0.83$ for children and $M = 0.91$ for adults, both greater than chance, $ps < .001$, $ds > 2.3$.

The primary analyses focused on the comparison of the performance in induction between children and adults (see Fig. 7). Similar to Experiment 2, adults provided more category-based responses than children, $t(37.5) = 6.66$, $p < .001$, $d = 1.9$, with adults relying on category information, $M = 0.73$, above chance, $p = .001$, $d = 0.8$, whereas children relying on appearance information, $M = 0.29$, below chance, $p < .001$, $d = 1.3$.

To examine whether basic-level categories had different effects from ontological-level categories, we further compared participants' induction performance of Experiment 3 to that of Experiment 2. Two independent-sample t-tests were performed for each age group. Specifically, for children, the proportion of category-based responses did not differ between two experiments, $p = .718$, $d = 0.1$, with the participants in both experiments equally likely to rely on appearance information. However, for adults, the proportion of category-based responses was higher in Experiment 2 than that in Experiment 3, $t(41.1) = 2.93$, $p = .006$, $d = 0.8$, indicating that adults benefited from the ontological-level distinctions. This is an important finding demonstrating that, in contrast to predictions of the knowledge-based approach, children do not exhibit greater reliance on category information when categories differ at the ontological level than when they differ at the basic level. Furthermore, the fact that adults exhibited such a difference suggests that the difference may be a product of development.

Overall, results of Experiment 3 replicated and further extended those of Experiment 2. When the attentional factor was not introduced, children ignored category information and relied on appearance

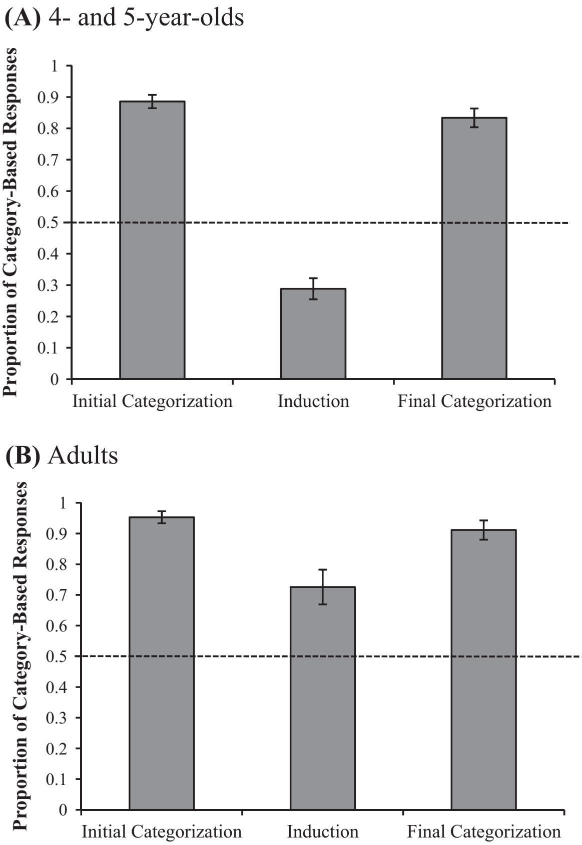

Fig. 7. Proportion of category-based responses in the categorization and induction tasks in Experiment 3. The chance level is 0.5. Error bars represent standard errors of mean.

information in their induction, even when rich conceptual information was provided. However, adults relied on category information when performing induction, more so when the distinction between the categories was at the ontological than at the basic level.

Estimates of the contribution of conceptual and attentional factors across Experiments 1–3. To estimate the contribution of conceptual and attentional factors respectively, we used data from all conditions combined (i.e., C+A+, C+A−, C−A+, and C−A−). Specifically, for the C+A+ condition, we used the data of 4- and 5-year-olds and adults in GD' Experiment 2. For the C+A− condition, we used the data of 4- and 5-year-olds and adults in our Experiment 2. For the C−A+ condition, we used the data of 4- and 5-year-olds and adults in our Experiment 1. And for the C−A− condition, we used the data of 4- and 5-year-olds and adults in GD's Experiment 1. The mean proportions of category-based responses in induction for each condition, as well as the effect sizes of conceptual and attentional factors (*Cohen's d*), are presented in Table 3.

As shown in the table, the contributions of conceptual and attentional factors to reliance on the category rule differed between age groups. For 4- and 5-year-olds, there was a large effect of attentional factors, $d = 1.86$, whereas the contribution of conceptual information had a negligibly small effect, $d = 0.20$. In contrast, for adults, there was a relatively greater effect of conceptual factors ($d = 0.68$) than that of attentional factors ($d = 0.40$).

These analyses point to two important differences between young children and adults. First, while adults clearly demonstrated category-based induction across conditions, pattern of induction of young children was responsive to attentional factors: Unless attentional factors were introduced, young children tended to demonstrate similarity-based induction. And second, while adults benefitted from ontological distinctions, these distinctions exerted negligible influence on children's pattern of induction.

These results also falsify an important prediction formulated within the knowledge-based approach that children are flexible in their inductive inferences, using perceptual similarity when categories have a weak conceptual basis, but using category membership for categories with a stronger conceptual basis" (Gelman & Davidson, 2013). In contrast to this prediction, conceptual basis played no appreciable role in the pattern of induction exhibited by young children. Whenever children exhibited flexibility, this was in response to attentional and not conceptual factors.

As shown in the analyses above, the basis of induction and the conceptual influences change in the course of development. However, the developmental time course of this transition is not clear. There is some evidence (e.g., Badger & Shapiro, 2012; Fisher & Sloutsky, 2005) that the transition is gradual, with children achieving adult-like levels of performance after 7 years of age. The goal of Experiments 4–5 was to address this question and to gain a better understanding of the development of category-based induction. Specifically, we replicated SKF (i.e., C−A−) and our Experiment 2 (i.e., C+A−) with 7-year-olds. We then estimated the developmental changes in conceptual contributions to category-based induction based on the data of 4- and 5-year-olds, 7-year-olds, and adults.

5. Experiment 4: Induction in older children in the absence of conceptual information

5.1. Method

5.1.1. Participants

Twenty-five elementary-school-age children (M = 7.59 years, SD = 0.27 years, range = 7.13–7.99 years; 9 girls) participated in this experiment. Four additional children were tested but excluded from the sample because they either failed to learn the category (N = 3) or got interrupted during the experiment (N = 1). In Experiments 4–5, children were recruited from elementary schools, located in middle-class suburbs of Columbus, Ohio, and were tested by an experimenter in a quiet room in their school.

5.1.2. Materials

Materials were similar to those of Experiment 3 with two differences. First, the response cues (i.e., drawings of tree and desert) were introduced, not as habitat, but as the pictures ziblets and flurps liked. Second, the descriptions of the category rule did not include any conceptual information. Specifically, participants were only told that ziblets had more fingers than buttons whereas flurps had more buttons than fingers.

5.1.3. Design and procedure

The design and procedure were similar to that of SKF, as well as GD's Experiment 1 (i.e., C−A−) in that neither conceptual nor attentional factors were introduced.

5.2. Results and discussion

The overall results are presented in Fig. 8. Similar to Experiments 1–3, the preliminary analyses focused on whether participants learned the categories and remembered the category rule over the course of experiment. Participants who passed the categorization criterion were highly accurate in the initial categorization task, $M = 0.90$, greater than chance, $p < .001$, $d = 3.9$. Their performance remained highly accurate in the final categorization task, $M = 0.88$, greater than chance, $p < .001$, $d = 3.3$.

The primary analyses focused on the comparison of the performance in induction to the chance level (see Fig. 8). Similar to the 4- and-5-year-olds in Experiments 2–3, the 7-year-old children in

Table 3
Mean (*SD*, sample size) proportions of category-based responses in induction and effect sizes of conceptual (C) and attentional (A) factors in four experimental conditions. (A) 4- and 5-year-olds; (B) adults.

Experimental condition		Effect size	Averaged effect size
(A) 4- and 5-year-olds			
C−A−: 0.28 (0.15, *N* = 16)	C−A+: 0.66 (0.27, *N* = 24)	$d_{A(C-)} = 1.65$	$d_A = 1.86$
C+A−: 0.27 (0.23, *N* = 24)	C+A+: 0.78 (0.27, *N* = 16)	$d_{A(C+)} = 2.07$	
C−A−: 0.28 (0.15, *N* = 16)	C+A−: 0.27 (0.23, *N* = 24)	$d_{C(A-)} = -0.05$	$d_C = 0.20$
C−A+: 0.66 (0.27, *N* = 24)	C+A+: 0.78 (0.27, *N* = 16)	$d_{C(A+)} = 0.44$	
(B) Adults			
C−A−: 0.75 (0.31, *N* = 24)	C−A+: 0.85 (0.29, *N* = 24)	$d_{A(C-)} = 0.33$	$d_A = 0.40$
C+A−: 0.93 (0.19, *N* = 24)	C+A+: 1.00 (0.02, *N* = 16)	$d_{A(C+)} = 0.47$	
C−A−: 0.75 (0.31, *N* = 24)	C+A−: 0.93 (0.19, *N* = 24)	$d_{C(A-)} = 0.70$	$d_C = 0.68$
C−A+: 0.85 (0.29, *N* = 24)	C+A+: 1.00 (0.02, *N* = 16)	$d_{C(A+)} = 0.66$	

Experiment 4 ignored category information, relying instead on appearance information, $M = 0.29$, below chance, $t(24) = 4.48$, $p < .001$, $d = 0.9$.

Results of Experiment 4 indicate that 7-year-olds, similar to 4- and 5-year-olds, and in contrast to adults in GD (Experiment 1), perform similarity-based induction when neither conceptual nor attentional factors are present. In Experiment 5, we further tested whether providing children with a conceptual basis for categories would lead to category-based induction in 7-year-olds.

6. Experiment 5: induction in older children in the presence of conceptual information

6.1. Method

6.1.1. Participants

Twenty-four elementary-school-age children ($M = 7.62$ years, $SD = 0.26$ years, range = 7.05–7.99 years; 11 girls) participated in this experiment. Two additional children were tested but excluded from the sample because they failed to learn the category.

6.1.2. Materials, design and procedure

The materials, design, and procedure were identical to those of Experiment 2 (i.e., C+A−).

6.2. Results and discussion

The overall results are presented in Fig. 9. Similar to Experiments 1–4, the preliminary analyses focused on whether participants learned the categories and remembered the category rule over the course of experiment. Participants who passed the categorization criterion were highly accurate in the initial categorization task, $M = 0.93$, greater than chance, $p < .001$, $d = 5.2$. Their performance remained highly accurate in the final categorization task, $M = 0.90$, greater than chance, $p < .001$, $d = 3.3$.

The primary analyses focused on the comparison of the performance in induction to the chance level (see Fig. 9). Unlike what we found in any of the experiments reported above, the performance of the 7-year-old children in Experiment 5 was not significantly different from chance, $M = 0.58$, $t(23) = 1.07$, $p = .297$, $d = 0.2$.

Because of the near chance performance, we deemed it necessary to analyze the individual patterns of responses. Participants who made category-based responses in at least 75% of trials (9 out 12) were classified as category-based responders, whereas participants who did so on no more than 25% of trials (3 out of 12) were classified as similarity-based responders. Of the 24 children, 50% (12 participants) were category-based responders and 33.3% (8 participants) were similarity-based responders, with the remaining 16.7% being mixed responders. In contrast, only 4% (1 out of 24 participants) of 4- and 5-year-olds in Experiment 2 were category-based responders, compared to 67% (16 participants) similarity-based responders. Therefore, there were more category-based responders and fewer

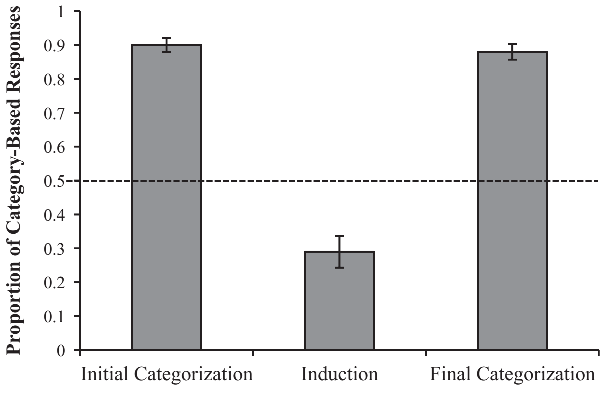

Fig. 8. Proportion of category-based responses in the categorization and induction tasks in Experiment 4. The chance level is 0.5. Error bars represent standard errors of mean.

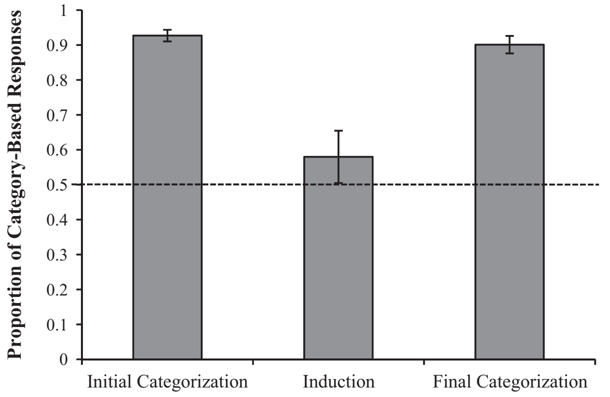

Fig. 9. Proportion of category-based responses in the categorization and induction tasks in Experiment 5. The chance level is 0.5. Error bars represent standard errors of mean.

similarity-based responders among 7-year-olds compared to 4- and 5-year-olds, $\chi^2(2, N = 48) = 12.793$, $p = .002$. Results of Experiment 5 coupled with those of Experiment 2 demonstrate that children start to make use of conceptual basis of categories and perform category-based induction with novel categories around the age of 7.

The development of category-based induction. To better understand the development of category-based induction, we further estimated the developmental changes in conceptual contributions to category-based induction with the data of 4- and 5-year-olds, 7-year-olds, and adults in the C−A− and C+A− conditions. Specifically, for the C−A− condition, we used the data of 4- and 5-year-olds and adults in GD' Experiment 1, and the data of 7-year-olds in our Experiment 4. For the CA− condition, we used the data of 4- and 5-year-olds and adults in our Experiment 2, and the data of 7-year-olds in our Experiment 5. The mean proportions of category-based induction for each condition across three age groups, as well as the effect sizes of conceptual information (*Cohen's d*), are presented in Table 4.

As shown in Table 4, conceptual contributions to category-based induction differed across age groups. For 4- and 5-year-olds, conceptual information had little effect on their induction, and they performed similarity-based induction regardless of the condition. In contrast, adults consistently relied on the category rule across the conditions, but seemed to get an additional boost from conceptual information.

Table 4
Mean (*SD*, sample size) proportions of category-based responses in induction and effect size of conceptual information in two experimental conditions across three age groups.

Age group	Experimental condition		Effect size of conceptual information
	C−A−	C+A−	
4- and 5-year-olds	0.28 (0.15, *N* = 16)	0.27 (0.23, *N* = 24)	−0.05
7-year-olds	0.29 (0.23, *N* = 25)	0.58 (0.27, *N* = 24)	0.95
Adults	0.75 (0.31, *N* = 24)	0.93 (0.19, *N* = 24)	0.70

For 7-year-olds, conceptual information had large effect on their induction, by pushing half of the sample from similarity-based to category-based induction. Therefore, 7-year-olds are a transitional group, with a half of the sample relying on conceptual information and a half ignoring it.

7. General discussion

7.1. Summary of findings

The primary goal of the five reported experiments was to examine the development of induction by estimating the contribution of conceptual factors to inductive inference across development. This was done with novel categories (induction with familiar categories may exhibit a different developmental pattern). The following findings stem from the reported experiments.

First, when making inductive inferences about newly-learned categories, 4- and 5-year-olds are responsive to attentional factors, but ignore conceptual information, whereas adults and many 7-year-olds benefit from conceptual information. Second, in the absence of attentional factors, the default pattern of induction in 4- and 5-year-olds is similarity-based, whether conceptual information is provided or not, whereas the default pattern in adults appears to be category-based (although see GD, Experiment 5). Third, the level at which newly-learned categories differ (i.e., ontological vs. basic-level) has little effect on induction in 4- and 5-year-olds, whereas adults benefit from a broader ontological distinction. This set of findings disputes the very core of the knowledge-based approach by presenting evidence that conceptual information (including deep ontological distinctions) does very little to affect early induction. Therefore, these results support SKF's conclusion that early in development inductive inferences about newly-learned categories are based primarily on appearance information.

The second set of findings pertains to the development of category-based induction. First, effects of conceptual information on induction increase with age, with 7-year-olds being a transitional group. And second, similar to 4- and 5-year-olds, when neither conceptual nor attentional factors are introduced, 7-year-olds perform similarity-based induction. However, in contrast to 4- and 5-year-olds, when only conceptual information is available, half of 7-year-olds perform category-based induction. This set of findings suggests that induction undergoes development between early childhood and adulthood, with 7-year-olds being a transitional group exhibiting evidence of effects of conceptual information on induction.

The reported findings have multiple implications, some of which are more local in nature, whereas others are more general. In terms of more local implications the reported results offer an alternative interpretation of GD findings, suggesting that the effects reported by GD stem from attentional manipulations that GD introduced rather than from additional conceptual information.

In terms of more global implications, these results expand our understanding of the mechanism of early induction, the development of induction, as well as more general understanding of cognitive development. In what follows, we consider each of these implications.

7.2. GD Conclusions in light of the reported findings

Recall that SKF found evidence of only similarity-based induction in young children. At the same time, upon adding conceptual information to the studied categories, GD found evidence for category-based induction in young children. Putting these two sets of findings together, GD concluded that children have the capacity for both, relying on similarity when no conceptual information is available, and relying on theory when conceptual information is available.

Our examination of GD's procedures suggested that in addition to providing children with conceptual information, they also introduced a number of attentional manipulations. By varying both factors orthogonally, we found that attentional factors do all the work in changing the pattern of early induction from similarity-based to category-based[4] (effect size = 1.86), whereas little work was done by conceptual information (effect size = 0.20). Therefore, it is likely that the pattern of category-based induction observed by GD stemmed from manipulations resulting in attracting children's attention to the category-defining rule. In fact, there is recent evidence by Deng and Sloutsky (2015) demonstrating that attracting children's attention to the category-defining rule is a powerful manipulation affecting their categorization decisions, without affecting their category-representations: these representations proved to be stubbornly similarity-based. In sum, the reported results indicate that, despite GD claims, there is little evidence that conceptual information affects the pattern of early induction.

7.3. The Mechanism of early induction

In addition to questioning the conclusions reached by GD, our findings have general implications for understanding the mechanisms of early induction: one of the goals of this research was to adjudicate between the knowledge-based and similarity-based mechanisms of induction. Recall that according to the *knowledge-based* approach, when the task is to generalize properties of some natural kind categories (such as animal kinds), induction is driven by conceptual knowledge. This knowledge is implemented as a set of conceptual assumptions, including the category assumption and the linguistic assumption (Gelman et al., 1998; see also Gelman, 2004; Murphy, 2002, for reviews). On the basis of these assumptions, when performing inductive generalizations, people, including young children, first identify the category of an entity (using either provided or self-generated labels) and then generalize properties of the entity to other members of the identified category. In short, according to this view, induction is based on prior categorization of presented entities, and is thus category-based.

According to the *similarity-based* approach, conceptual knowledge is a product rather than a precondition of development and learning, and early in development cognitive processes do not depend on *a priori* conceptual knowledge. Instead they are grounded in powerful learning mechanisms, such as statistical and attentional learning. According to this approach, early in development both categorization and induction are similarity-based. Note that there are several critical differences in how each approach construes the mechanism underlying early induction: the knowledge-based approach postulates that inductive inference from one item to another is based on an identification of a category common to the two items, whereas the similarity-based approach argues that these processes are relatively independent (see Sloutsky & Fisher, 2004a; Sloutsky et al., 2007a, for relevant discussion). Data reported by SKF provided clear evidence for the similarity-based mechanisms of early induction.

In response to these findings, the knowledge-based account was modified by GD to accommodate SKF findings and making an important prediction that children are flexible in their inductive inferences. According to this modification, children are expected to use perceptual similarity when categories have a weak conceptual basis, but to use category membership for categories with a stronger conceptual basis (Gelman & Davidson, 2013). However, the reported results present evidence against this prediction, indicating that regardless of conceptual basis of the studied categories, early induction is similarity-based. Therefore, the reported findings provide further support for the similarity-based mechanisms of early induction, while posing strong challenges to the knowledge-based account.

7.4. The development of induction: from similarity-based to category-based

One of the goals of the current research was to examine whether induction undergoes development, as well as what changes and why. The current research provides clear answers to the *whether*

[4] Although we use the term "category-based" here, as we discuss in the *Introduction* and in the *General Discussion*, we cannot be certain that induction was in fact category-based. This is because GD used featural rather than relational rules thus enabling participants to perform induction by feature matching.

and *what* questions, as well as some speculative responses to the *why* question. The results clearly indicate that induction changes in the course of development: whereas young children exhibit primarily similarity-based induction, adults and some older children can perform category-based induction.

In addition to this broad answer, the reported research provides a number of more nuanced answers. First, there is evidence that, whereas adults can perform category-based induction even in the absence of attentional cuing, young children need an extra "push" to do so. This finding is consistent with a recent result by Deng and Sloutsky (2015) examining the development of category learning. These researchers presented 4-year-olds with a category-learning task, with categories consisting of a single deterministic feature and multiple probabilistic features. They found that in the absence of attentional cuing, adults learned the deterministic feature (i.e., the category rule) and used it in categorizing new items, whereas 4-year-olds learned multiple probabilistic features (i.e., appearance information) and used these when categorizing new items. However, when children's attention was attracted to the deterministic feature during category learning, their categorization became adult-like in that they learned deterministic feature and used it for categorization. Taken together, these results point to an important change in attention that affects the category learning and (potentially) inductive inference. Whereas adults can successfully focus their attention internally (they have sufficiently developed top-down selective attention), young children need external guidance to focus their attention.

The second (and more novel) finding of this research is the increasing ability to rely on conceptual information in the course of induction. There are previous reports pointing to protracted development of category-based induction (e.g., Badger & Shapiro, 2012; Fisher & Sloutsky, 2005). However, these previous studies did not manipulate conceptual information provided to children during induction and therefore they cannot estimate the development of the ability to use conceptual information in induction. The current study presents evidence that whereas conceptual information did not affect patterns of induction of 4- and 5-year-olds, 7-year-olds and adults benefited from conceptual information.

Taken together these results suggest that both the ability to attend selectively and the ability to use conceptual information increase with age and that these changes contribute to the development of category-based induction. Finally, the current results present further evidence that category-based induction is not a developmental default – it undergoes protracted development extending well into the elementary school years: even among 7-year-olds, only half of the sample benefitted from exposure to conceptual information. These results advance our understanding of the development of induction, and, as we discuss below, they may advance our understanding of more general mechanisms of cognitive development.

7.5. Broader implications for understanding cognitive development

The knowledge-based and the similarity-based accounts of inductive inference represent more general theoretical traditions that offer radically different views of cognitive development. The fundamental idea of the knowledge-based accounts is that cognitive development is driven by pre-existing (or even *a priori*) domain-specific knowledge manifesting itself in the form of assumptions, biases, skeletal principles, or theories. As argued by Wellman and Gelman (1992), *a central mechanism of cognitive development is the early acquisition of foundational theories of core domains of human understanding* (p. 371). These domains differ in terms of the basic properties of ontological units (e.g., self-propelled motion in the domain of biology or mechanical motion in the domain of physics), interaction among these units, and within-domain causality. Even infants are said to be equipped with understanding these domain-specific principles as well as differences among the domains (e.g., Spelke, 1994; Spelke, Phillips, & Woodward, 1995). Much of this knowledge is *a priori* and it constrains subsequent learning within these domains.

Research reported here challenges some of these views by presenting evidence that rich conceptual information (that is supposed to trigger domain-specific induction in the domain of biology) did not do so until at least 7-years of age. Such a late emergence of the effects of conceptual information suggests that domains may not be *a priori*, but may be themselves products of development.

The theoretical view that explains development in terms of changes in *a priori* knowledge contrasts sharply with a view that attributes development to a change in domain-general basic processes. According to the latter view, domains themselves can emerge from more general cognitive constraints coupled with rich inputs (cf. Goldstone & Landy, 2010), and development is a much more domain-general process than suggested by the proponents of the knowledge-based approach. Such more domain-general approach to development suggests that, although knowledge is an important contributing factor (i.e., that is how learning contributes to development), knowledge is not *a priori*, but is a result of development and learning. Furthermore, other important drivers of development are changes in the underlying cognitive processes, such as attention, memory, and cognitive control (e.g., Johnson, 2010; Sloutsky, 2010; Smith & Samuelson, 2000; Twyman & Newcombe, 2010).

This joint contribution of more basic processes and emerging (rather than *a priori*) knowledge to cognitive development is exemplified by recent evidence pertaining to the development of induction with familiar categories (Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen, & Unger, 2015). These researchers examined induction when familiar semantically-related labels (e.g., *crocodile* and *alligator*) were provided, but appearance information was not. The primary focus was on induction to a taxonomically proximal item (e.g., from crocodile to alligator) versus induction to an unrelated lure (e.g., from crocodile to butterfly). Results indicated that whereas 4-year-olds exhibited just above-chance performance in generalizing properties to a close taxonomic match, 5- and 7-year-olds were near ceiling. Interestingly, some of these developmental differences could be explained by differences in semantic knowledge, as evidenced by correlations between semantic knowledge and choices of taxonomically-related items. However, semantic knowledge accounted for approximately 20% of variance in induction performance. Therefore, there are likely to be other contributing factors, perhaps changes in basic cognitive processes, such as working memory (see Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen, & Unger, 2015).

Research reported here, in particular developmental differences in induction in the absence of attentional or conceptual support, presents clear evidence for the importance of domain-general factors for cognitive development. These putative factors may include developmental changes that underlie the ability to learn more abstract categories. These include an increasing ability to integrate auditory and visual information, which results in changes in the role of linguistic labels in categorization and induction (Robinson & Sloutsky, 2007, 2008; Sloutsky & Fisher, 2004a; see also Sloutsky, 2010 for a discussion) and the ability to attend selectively to some aspects of information and ignore others (Best, Yim, & Sloutsky, 2013; Deng & Sloutsky, 2012, 2013, 2015; Kloos & Sloutsky, 2008; see also Hanania & Smith, 2010; Sloutsky, 2010 for discussion).

7.6. Possible objections and questions for future research

We believe that current research presents a compelling case for protracted development of category-based induction, with conceptual influences on induction being a product of development. At the same time, we envision a number of objections to this conclusion.[5] In what follows, we address some of these objections. We then formulate questions for future research.

7.6.1. Is there a problem with relational rules?

The reported work indicates that conceptual information is neither necessary for category-based induction of 4- and 5-year-olds (as evidenced by successful performance in the C−A+ conditions) nor sufficient for it (as evidenced by unsuccessful performance in the C+A− conditions). Although children clearly performed successfully in the C−A+ condition but not in the C+A− condition, it could be argued that the difference between the A− and A+ conditions is driven by the use of a relational rule in a former and a featural rule in the latter. If the relational rule makes induction exceedingly difficult for 4- and 5-year-olds, then there should be little surprise that children failed to perform category-based induction in this condition. While this argument does not undermine the central developmental

[5] We thank an anonymous reviewer for raising some of these objections.

findings of the current research, it may cast doubt on the conclusion that early induction is not category-based. We disagree with the argument for the following reason.

Note that while failing to base their induction on the relational rule, children did not universally succeed on the featural rule. For example, Badger and Shapiro (2012) used a featural rule and failed to find reliable evidence of category-based induction in children younger than 6- to 7-years of age. Similarly, as shown by Experiment 7 of GD, 4- and 5-year-old children did not rely on the featural rule unless their attention was explicitly attracted to this rule by the category contrast. Therefore, the sole difference between the featural and the relational rules cannot explain the difference in performance between the A+ and A− conditions.

Another variant of this concern is that whereas children can perform categorization with a relational rule, somewhat higher task demands of induction prevent them from doing so. This is also a potentially important concern and we addressed it in the control experiment (Experiment 2A). Recall that this experiment reports a control condition in which we trained 4- and 5-year-olds to perform induction with the relational rule. Results indicated exceedingly high induction accuracy ($M = .92$), comparable with to levels of accuracy when children learned categories based on the relational rule. Therefore, there is no evidence that induction per se is a more difficult task than categorization. What seems to be difficult is to base induction on category membership when there is no directly observable or explicitly highlighted information marking the category.

7.6.2. Doesn't reliance of young children on a featural rule when performing induction indicate that their induction is category-based?

Another potential objection is this: Children (at least in some conditions) successfully based their induction on a rule when the rule was featural rather than relational, so why cannot this induction be category-based. In our view, the problem with this argument is that feature-based induction is ambiguous (i.e., it can be either similarity-based or category-based) and ambiguity cannot be counted as supporting a particular position. To remind, SKF introduced a relational rule to prevent induction based on simple feature matching, which could be a variant of similarity-based induction. When the rule is featural, such as in GD and in A+ conditions of the present research, induction could be performed on the basis of feature matching (rather than accessing a common category). Therefore, successful reliance on a featural rule does not **uniquely favor** category-based induction.

There is also direct evidence that feature-based induction may not be category-based (see Deng & Sloutsky, 2012, 2013). Specifically, Deng and Sloutsky (2012, 2013) presented evidence that if a feature is salient enough to capture attention, participants rely on this feature when performing induction, while ignoring the rest of the features and the category label (which is supposed to be an ultimate category-marker). These researchers taught participants two categories. The categories had a family resemblance structure, with the most salient feature being a deterministic one in that it perfectly distinguished between the two categories. In addition, there were two category labels and a category label accompanied each item, such that the labels also distinguished perfectly between the categories. During testing participants were presented with an induction task that had two types of test trials: the high match trials were similar to training, whereas the low match trials were in fact switch items, they pitted the highly salient feature from Category A against the label and some of the features of Category B. Thus, participants could rely in their induction either on the label and other features or on the most salient feature. The results indicated that, in contrast to adults, 4- and 5-year-olds relied on the most salient feature (even though they had excellent memory for category labels). The fact that children preferred salient features to category labels strongly indicates that their induction is feature-based rather than category-based. And if one argues that even in these circumstances children's induction was category-based, then they need to agree that labels for young children are not category markers, something that runs against the very core of the knowledge-based approach (see Gelman & Coley, 1991).

Thus, whereas there is direct evidence that feature-based induction may **not** be category-based, we are unaware of any direct evidence that feature-based induction **is** category-based. Therefore, given that (a) feature-based induction is ambiguous in that it could be indicative either of similarity-based induction (through feature matching) or of category-based induction and (b) there is direct evidence that feature-based induction may not be category-based, the long standing belief that early induction is category-based can no longer be accepted as a default. The burden of proof has shifted to the proponents of the early onset of category-based induction to demonstrate that early induction is indeed category-based and not similarity-based.

7.6.3. Are the factors that we described as attentional really "attentional"?

The third possible objection is whether the description of some of the factors as attentional is accurate. This description could be particularly problematic with respect to relational category rule versus feature-based category rule contrast. Indeed, the distinction between the relational rule and featural rule may not be captured by the term "attentional" difference: while relations are more difficult to notice and attend to, they could be also more difficult to process and compute (e.g., Gentner & Kurtz, 2005; Halford, Wilson, & Phillips, 1998; Kotovsky & Gentner, 1996; Richland, Morrison, & Holyoak, 2006). There are several reasons for using the current description.

Recall that some of the factors introduced by GD are specific to natural kinds (we identify these factors as conceptual), whereas others are not limited to inputs in one bounded area of knowledge (see Keil, 1990, for a discussion of this distinction). In our view this distinction is important and we attempted to attract attention to it. In addition, recall that the target experiments in GD included **all** the putative "attentional" factors, which made it difficult to identify the independent contribution of each factor. Given that varying all these factors orthogonally would be prohibitively expensive, we decided to vary these factors jointly and describe them jointly as "attentional". As we discussed in the Introduction, these factors together may make it easier to attend to the category-relevant distinction, thus making young children's reliance on the rule possible.

7.6.4. Shouldn't the search for early onset focus on competence rather than performance?

One can argue that the focus of the debate between proponents of different theoretical positions is on whether preschoolers have the **ability** to engage in truly category-based (as opposed to similarity-based) induction? In other words, the debate is about their competence (which may transpire under the most supportive conditions) rather than about their performance (which may be limited when conditions are too difficult). We believe that the debate is not about whether a particular ability transpires in preschool age, but is rather about **development**: Is category-based induction an *a priori* ability reflecting domain-specific constraints and exhibiting an early onset or is it a product of domain-general developmental processes? Or perhaps more broadly: Is development guided and structured by *a priori* domain-specific constraints (R. Gelman, 1990) or is it a product of experience and domain-general factors (such as working memory, selective attention, or cognitive control)?

As we argued in Section 7.6.1, there is no direct evidence that preschoolers have the ability to perform category-based induction with novel categories, but there is much evidence (including this work) that this ability undergoes development (see also Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen, & Unger, 2015 indicating that category-based induction with familiar categories also undergoes development). Furthermore, even if preschoolers are shown to possess the ability to perform category-based induction under very supportive conditions, this is not evidence that this ability is either *a priori*, domain-specific, or exhibiting an early onset. However, the opposite is true: Given that firm evidence for category-based induction with novel categories does not appear until around seven years of age as shown in the current study (see also Badger & Shapiro, 2012; Fisher & Sloutsky, 2005), it is highly likely that this ability is a product of development rather than an *a priori* one.

In sum, it seems that GD's experiments failed to present a compelling case for the early onset of category-based induction, whereas the current research presented evidence for the protracted development of this critical ability. At the same time, despite a growing body of evidence that category-based induction and conceptual influences on induction undergo protracted development, little is known about the details of this development and factors contributing to it. Therefore much research is needed to understand these details and factors. Perhaps it would be more productive to focus future research efforts on understanding the development; attempts to find evidence for the early onset may prove elusive.

7.6.5. Additional questions for future research

Current research presents evidence that (1) early induction is similarity-based, (2) conceptual information plays negligible role in early induction, and (3) the role of conceptual knowledge increases in the course of development. We suggested that these changes are due to development and learning, with domains themselves emerging in the course of this development. We also suggested that important drivers of this development are changes in the underlying cognitive processes, such as attention, memory, and cognitive control. However, much research is needed to get a better and more precise understanding of how and why these changes occur.

There is also evidence that acquisition of conceptual knowledge may interact with general cognitive factors in driving the development of category-based induction. Note that there are two parallel lines of research examining the development of induction: Present work (as well as Badger & Shapiro, 2012; Deng & Sloutsky, 2012, 2013) examined induction with novel categories, whereas other work (e.g., Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen, & Unger, 2015; Godwin, Matlen, & Fisher, 2013) examined induction with familiar categories. While both lines of research present evidence for protracted development, in general, category-based induction manifests itself earlier when categories are familiar (but see Fisher & Sloutsky, 2005, for evidence for later onset of category-based induction with familiar categories).

Although this developmental asynchrony should be treated with caution due to differences in methodology and stimuli, it clearly suggests that neither general cognitive factors alone nor acquisition of conceptual knowledge (Fisher and colleagues referred to it as *semantic* knowledge) alone could explain the development of category based induction: in the former case, there should be no novelty-familiarity effect, whereas in the latter case, there should be no age effect. However, these conclusions are preliminary and more research is needed to investigate induction with familiar and novel categories in a single paradigm to directly examine these putative interactions.

7.7. Conclusion

The current research examines the mechanism of early induction, the development of induction, and the ways attentional and conceptual factors contribute to induction across development. The results suggest that early induction is similarity-based. The results also indicate that initially, conceptual information plays negligible role in induction, but its role increases gradually with age, with the 7-year-olds being a transitional group. And finally, there is substantial contribution of attention to the development of induction: whereas adults can perform category-based induction without attentional support, 4- and 5-year-olds and 7-year-olds need external attentional support. Therefore, contribution of conceptual information to induction increases gradually with development and category-based induction exhibit protracted development. Overall, these findings present challenges to the knowledge-based approach to induction, while supporting a more domain-general view of induction and its development.

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