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Similarity, Induction, Naming, and Categorization (SINC): Generalization or Inductive Reasoning? Reply to Heit and Hayes (2005)

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This article is a response to E. Heit and B. K. Hayes's (2005) comment on the target article "Induction and Categorization in Young Children: A Similarity-Based Model" (V. M. Sloutsky & A. V. Fisher, 2004a). The response discusses points of agreement and disagreement with Heit and Hayes; phenomena predicted by similarity, induction, naming, and categorization (SINC); and relationships between SINC and models of verbal inductive reasoning, as well as contributions and limitations of SINC and directions for future research. Overall, the authors disagree with Heit and Hayes's analysis of limitations of SINC and with their analysis of SINC in the context of verbal inductive reasoning. At the same time, the authors agree that more research is needed to provide a unified account of similarity, induction, categorization, and recognition.

Keywords: categorization, induction, cognitive development, recognition memory

The ability to extend knowledge from known to novel, or inductive generalization, and the development of this ability are interesting and controversial issues in human cognition. Some researchers have proposed a knowledge-based (or naïve-theory) approach, arguing that even early in development, conceptual knowledge is a critical component of induction (Gelman, 2003; Gelman & Wellman, 1991; Keil, Smith, Simons, & Levin, 1998). Others have suggested that inductive generalization may develop in a bottom-up manner, with similarity playing a critical role in early induction (Colunga & Smith, 2005; French, Mareschal, Mermillod, & Quinn, 2004; McClelland & Rogers, 2003; Sloutsky, 2003; Sloutsky & Fisher, 2004a). Whereas both positions agree that bottom-up processes, such as similarity computation, may play a role (e.g., Keil, 2003; Keil et al., 1998), they disagree as to whether it is necessary to posit conceptual knowledge to explain early induction.

In a recently published article (Sloutsky & Fisher, 2004a), we addressed this controversy by presenting theoretical arguments and empirical evidence suggesting that positing a significant role of conceptual knowledge in early induction is unnecessary and unwarranted. We also proposed a model of early similarity, induction, and categorization (SINC). Originally, SINC stood for similarity, induction, and categorization, but our more recent data discussed below suggest a more extended interpretation: similarity, induction, naming, and categorization.

SINC considers induction as a set of interrelated processes. For instance, (a) upon learning that an animal is called "fep," one can generalize this name to other similar animals; (b) upon learning that the fep is a mammal, one can generalize the category membership to other feps; and (c) upon learning that feps use serotonin for neural transmission, one can generalize this knowledge to other feps and possibly to other mammals. These forms of inductive generalization are referred to as (a) label extension, or naming, (b) categorization, and (c) projective induction. Because SINC considers these to be interrelated processes, unless specified otherwise, we use the term *induction* as a generic reference to each of these processes.

There are several theoretical assumptions underlying SINC, some of which have been confirmed empirically. First, early in development, the three processes described above are variants of the same process of automatic similarity-based generalization. Second, early in development, linguistic labels are features contributing to similarity of compared entities, with similarity computed over automatically detected perceptual and linguistic features. Further, various features may have different attentional weights and therefore different contributions to similarity and thus to induction. In particular, linguistic labels often have somewhat larger attentional weights than does appearance information. Unlike the knowledge-based approach, which argues that effects of labels stem from their conceptual importance, SINC argues that, early in development (because labels are features contributing to similarity), effects of labels stem from low-level attentional mechanisms. These theoretical assumptions enable a formal way of predicting early induction performance as well as the prediction of a number of interesting and novel phenomena.

In their commentary, Heit and Hayes (2005) discuss the strengths and weaknesses of SINC while placing it in a larger context of inductive reasoning. Although the commentary presents an impressive overview of the field of inductive reasoning, it places SINC in a wrong context, focusing on some of the apparent rather than real weaknesses while overlooking some real strengths and real limitations of SINC.

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In pointing to limitations of SINC, Heit and Hayes (2005) argue that (a) SINC fails to account for some of the well known inductive reasoning phenomena, and (b) SINC does not predict anything new compared with existing models of induction. We disagree with both arguments. The first argument, although factually true, puts SINC in a wrong context, as most of the inductive reasoning phenomena were demonstrated with adults.

The second argument is factually wrong because it misses a wide range of phenomena generated by SINC, which (in our view) distinguish it from other proposed models. Further, as we argue below, the attempt to express models of inductive reasoning in the currency of SINC leads to several contradictions. In what follows, we consider some of the arguments presented by Heit and Hayes and outline points of agreement and directions for future research.

Is Research on Inductive Reasoning an Adequate Context for Evaluating SINC?

Heit and Hayes (2005) suggest examining the contribution of Sloutsky & Fisher (2004a) by considering it in the wider context of research on inductive reasoning. Heit and Hayes then briefly discuss the 11 phenomena generated by the similarity-coverage model (SCM; Osherson, Smith, Wilkie, Lopez, & Shafir, 1990) and argue that SINC cannot account for most of these phenomena. Note that, according to SCM, induction is a function of similarity and of category information, whereas according to SINC, induction is a function of similarity (with labels contributing to similarity rather than providing category information). Therefore, whereas SINC is a model of early induction, we believe that SCM (because of its category component) is a model of mature induction.

Note that whereas phenomena generated by the category component of SCM were found in adults, evidence for these effects in children is equivocal. In particular, there are two studies that failed to find diversity effects in 5–6-year-olds or 8–9-year-olds (Gutheil & Gelman, 1997; Lopez, Gelman, Gutheil, & Smith, 1992) and one study that succeeded to find these effects in 5-year-olds (Heit & Hahn, 2001). There is also a study reporting typicality effects in 5–6-year-olds (Lopez et al., 1992); however, we recently proposed an alternative interpretation of these findings (Fisher & Sloutsky, 2005b, p. 595). Specifically, we presented evidence that these putative typicality effects could stem from the less typical animals being referred to by less familiar words.

In our view, these difficulties to find reliable evidence for the category component in young children reflect the fundamental differences between early and mature induction. Whereas the former is a similarity-based process of inductive *generalization*, the latter may involve a deliberate category-based *reasoning* component. Generalization is a relatively automatic process that does not require deliberate selective attention, whereas reasoning is a deliberate process of deriving conclusions from premises and evaluating these conclusions and/or arguments. Given that reasoning is likely to require deliberate control of attention, and given that the ability of young children to focus and shift attention deliberately is unclear (Kirkham, Cruess, & Diamond, 2003; Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004), children's ability to perform category-based inductive reasoning is questionable. Although Sloutsky and Fisher (2004a) did not explicate these arguments, they contrasted SINC (a bottom-up model of early inductive generalization) with a top-down, knowledge-based approach, which considers early induction as a variant of reasoning process (e.g., Gelman, 1988; Gelman & Markman, 1986).

In short, Heit and Hayes suggest considering SINC in the context of inductive reasoning, whereas we believe that this is a wrong context for the analysis of early induction. Further, as it is a model of inductive generalization, SINC (as we demonstrate below) enables the prediction of a wide range of interesting phenomena that models of inductive reasoning can neither predict nor account for.

What Is the Broader Context of SINC?

As mentioned above, SINC is a model implementing a theory of inductive generalization that can predict a wide range of phenomena across a variety of tasks. Some of these phenomena were presented in Sloutsky and Fisher's (2004a) study, whereas others appear elsewhere. These phenomena include (a) effects of labels on similarity early in development; (b) effects of phonological similarity of labels on induction; (c) low-level attentional mechanisms underlying effects of labels on similarity and induction; (d) flexible (yet nondeliberate) adjustment of attentional weights of different sources of information; (e) differential effects of induction on recognition memory at different points of development; (f) dissociation between label and category information; (g) integration of labeling and appearance information in the course of similarity judgment and induction; and (h) interrelationships among induction, categorization, naming, and similarity. Note that each of these phenomena includes many more specific effects. Whereas SINC and its underlying theory predict these effects, none of the models reviewed by Heit and Hayes can account for the first seven phenomena.

First, it has been demonstrated that, early in development, labels contribute to similarity of compared entities (Sloutsky & Fisher, 2004a; Sloutsky & Lo, 1999). In particular, when two entities share a label, young children tend to consider these entities as looking more alike than when the same entities are presented without labels, and as we explain below, these effects stem from attentional factors such as auditory information overshadowing (or attenuating processing of) corresponding visual information (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003).

Second, on the basis of the theoretical assumption that, early in development, linguistic labels are features contributing to the overall similarity, SINC predicts that phonological similarity of labels may contribute to induction. There is recent evidence supporting this prediction (Fisher & Sloutsky, 2004): Young children were more likely to generalize a property from test item to a target item if the test and target items had a phonologically similar label (e.g., *Guma* and *Gama*) than if it had a phonologically different label (*Guma* and *Fika*). Further, young children tended to extend phonologically similar words to visually similar entities.

Third, according to SINC, effects of words on similarity and thus on induction stem from low-level attentional mechanisms rather than from an understanding of conceptual importance of labels. On the basis of this idea, it was predicted that words, as well as other auditory stimuli, may affect processing of corresponding visual information. This prediction was confirmed empirically: For infants and young children, auditory information overshadows corresponding visual information (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). In particular, when discriminable visual and auditory stimuli (including human speech) were presented together, discrimination of visual (but not of auditory) stimuli decreased compared with a unimodal baseline. Fourth, because effects of words and visual information on induction stem from attentional mechanisms rather than from understanding of the conceptual importance of labels or appearances, SINC predicts that contribution of labels or appearance to induction can be changed by changing the attentional weights of labels or appearance through associative training. This prediction was supported in a set of experiments (e.g., Sloutsky & Spino, 2004) in which attention to labels or to appearances was manipulated by varying their predictive values (when a cue is consistently nonpredictive, attention to this cue decreases; see Hall, 1991, for a review). After training, participants were presented with an induction task, which was repeated 3.5 months after training. It was found that, as a result of training, young children exhibited (depending on the training condition) either appearance-based or label-based induction, with either pattern being different from pretraining induction. Further, 3.5 months after training, young children retained these effects of training.

Fifth, SINC enabled a novel prediction regarding effects of induction on recognition memory. Recall that, according to SINC, early induction is driven by similarity, whereas according to the knowledge-based approach, even early in development. induction is category based and is driven by more abstract category information. Sloutsky and Fisher (2004a) developed the induction-then-recognition (ITR) paradigm, allowing the distinction between these two possibilities.

The ability of ITR to distinguish between these possibilities is based on the following reasoning. Research on false-memory phenomena has shown that deep semantic processing of studied items (including grouping of items into categories) often increases memory intrusions—false recognition and recall of nonpresented "critical lures" or items semantically associated with studied items (e.g., Koutstaal & Schacter, 1997; Thapar & McDermott, 2001; Toglia, Neuschatz, & Goodwin, 1999). Thus "deeper" processing can lead to lower recognition accuracy when critical lures are semantically similar to studied items. In contrast to deep processing, focusing on perceptual details of pictorially presented information results in accurate recognition (Marks, 1991). Therefore, a memory test administered after an induction task may reveal information about how items were processed during the induction task. If participants processed the items relatively abstractly as members of a category (i.e., they performed category-based induction), then they would likely have difficulty discriminating studied targets from conceptually similar critical lures. If, on the other hand, they processed items more concretely, focusing on perceptual details (i.e., they performed similarity-based induction), then they should discriminate relatively well. This is exactly what Sloutsky and Fisher (2004a, 2004b; Fisher & Sloutsky, 2005b) found. After performing induction with pictures of members of familiar categories (e.g., cats), young children exhibited greater recognition accuracy than did adults, with recognition gradually decreasing with increasing age.

Sixth, SINC clearly differentiates between labeling information and category information. According to SINC, linguistic labels contribute to induction by contributing to similarity rather than by denoting categories. Initial evidence for this distinction comes from the fact that young children's induction is not category based (Fisher & Sloutsky, 2005b; Sloutsky & Fisher, 2004a, 2004b), yet labels contribute to early induction by affecting similarity (Sloutsky & Fisher, 2004a; Sloutsky, Lo, & Fisher, 2001).

More direct evidence for the distinction comes from a set of recent studies that use the ITR paradigm (Fisher & Sloutsky, 2005a). Note that in the ITR-paradigm recognition studies discussed above (Fisher & Sloutsky, 2005b; Sloutsky & Fisher, 2004a, 2004b), pictures were not accompanied by labels. If label and category information are the same for young children, then when presented entities are labeled, children should exhibit effects of semantic processing (low recognition accuracy stemming from high hits and elevated false alarms). Further, effects of category labels (i.e., the word *cat* referring to each individual cat) should differ from those of individual nonsense labels (i.e., a different nonsense count noun referring to each member of a category). In particular, only the former, but not the latter, should promote category-based induction. However, because SINC does not consider category labels to be category markers, the prediction is different. In particular, because labels may overshadow corresponding visual information, introduction of labels may disrupt encoding of visual information, thus resulting in a decreased proportion of hits. Further, category labels and individual nonsense labels should have comparable effects on recognition memory.

This is exactly what was found when category labels were introduced in the ITR paradigm: In contrast to the no-label condition where the proportion of hits was above chance, in the label condition, the proportion of hits dropped to chance, whereas the proportion of false alarms was unaffected by labeling (Fisher & Sloutsky, 2005a). Further, our unpublished data indicate that category labels and individual nonsense labels exert similar effects on patterns of recognition memory of young children. However, when young children were trained to perform category-based induction (Fisher & Sloutsky, 2005a), not only did their induction performance increase, but participants also exhibited patterns of recognition accuracy that were similar to those of adults (i.e., high hits and elevated false alarms).

These results support the distinction between category information and labeling information for young children. It seems, however, that Heit and Hayes (2005) overlook this distinction. In particular, in reference to an apparent contradiction between the results of Sloutsky and Fisher's (2004a) Experiments 1 and 5, Heit and Hayes (2005) write that

> Experiment 1 was a similarity judgment task comparing children and adults, and the main result was that children were influenced by shared *category labels* (italics added) but adults were not. *In contrast* (italics added), Experiment 5 had the opposite pattern of results. Children's recognition judgments were unaffected by *category membership* (italics added), but adults showed a distinctly categorical pattern. (p. 603)

The appearance of the contradiction may arise only if one treats category labels and category membership as the same, whereas if one acknowledges the difference between the two, there is no contradiction between the results of Experiments 1 and 5. In neither experiment were young children influenced by category information, and in both experiments, their induction was driven by the overall similarity (computed over visual and labeling features in Experiment 1 and over visual features only in Experiment 5).

Seventh, labels and visual similarity jointly contribute to induction early in development, and unless trained to do so, young children do not selectively attend to labeling or appearance information. Further, SINC can quantify this contribution: For example, SINC accurately predicted young children's performance on individual triads with Gelman and Markman (1986) stimuli, and as predicted, children's induction was driven by the overall similarity rather than by reliance on labels. Finally, SINC assumes the interrelatedness of similarity, induction, and categorization, and results reported by Sloutsky and Fisher (2004a) support this assumption, pointing to high intercorrelations among similarity, induction, and categorization.

In sum, SINC predicts a large number of phenomena pertaining to early similarity judgment, induction, categorization, lexical extension, and recognition memory. Further, as we discuss in the next section, most of these phenomena cannot be predicted or accounted for by other models of induction.

SINC and Models of Verbal Induction

When discussing SINC vis-à-vis models of inductive reasoning, Heit and Hayes (2005) try to convert these models into the "currency" of SINC, thereby demonstrating that predictions of SINC are indistinguishable from those of models of inductive reasoning. In the previous section, we presented evidence that this argument is factually wrong—SINC does predict phenomena that cannot be predicted (or accounted for) by models of verbal inductive reasoning. In this section, we argue that this attempted conversion leads to contradictions.

First, unlike SINC, none of the models reviewed by Heit and Hayes differentiates between labeling information and category information; they consider both kinds of information to be equivalent. The principled reason for SINC to be able to differentiate between the two kinds of information is the "label-as-attribute" hypothesis (see Sloutsky & Fisher, 2004a; Sloutsky & Lo, 1999; Sloutsky et al., 2001), which as we argued above, is one of the major contributions of Sloutsky and Fisher (2004a) and of SINC in general. The hypothesis posits that, for young children, labels are features contributing directly to similarity rather than making an indirect contribution by communication that identically labeled items belong to the same category and thus are more similar. This hypothesis led to predictions that (a) there is a dissociation between label and category information and thus between label-based and category-based induction; (b) phonological similarity of labels contributes to induction; and (c) attentional weights of labels can be flexibly adjusted in the course of associative training. Because none of the discussed models predicts that labels directly contribute to similarity or that there is a dissociation between label and category information, none of the models can either predict or account for these effects. Therefore, the attempted conversion is highly questionable because it either (a) grants the Rips (1975) and Sloman (1993) models the assumptions that they do not make (i.e., that labels directly contribute to similarity) or (b) treats labels as an equivalent of category information for SCM (Osherson et al., 1990) and Heit (1998) models, which, as we demonstrated above, is not true, at least for young children.

Further, the mechanism by which labels contribute to induction proposed by SINC is very different from that in other models (such as SCM and Heit's, 1998, model). The latter becomes especially true when mechanisms underlying induction are examined more closely. In particular, because SINC considers labels as attributes contributing to the overall similarity, it can predict that the phonological similarity of labels may also contribute to the overall similarity and thus to induction.

This contribution of phonological similarity of labels to the overall similarity can be captured by the following equation:

$$\mathrm{Sim}(\mathrm{B},\mathrm{T}) = \lambda^{\beta} \upsilon^{B},$$

where λ and υ ($0 \leq \lambda, \upsilon \leq 1$) denote values (weights) of a label and visual information, respectively, and B and β denote the number of featural mismatches between the appearance and the label of Test B and the target, respectively. When there are no mismatches, $\beta = B = 0$, and $\lambda = \upsilon = 1$, the similarity between Test B and the target equals to unity.

Now, with the Luce choice rule and simple derivations, we can express the probability of inducing a property from Test B to the target:

$$P(B) = \frac{1}{1 + \dfrac{\lambda^{\alpha}}{\lambda^{\beta}} \dfrac{\upsilon^{A}}{\upsilon^{B}}},$$

where λ^{α} is the similarity of label of Test A to the label of the target, whereas λ^{β} is the similarity of label of Test B to the label of the target. Therefore, the probability of inducing a property from Test B to the target is a function of two similarity ratios: (a) the ratio of appearance similarities of each of the test items to the target's appearance and (b) the ratio of label similarity of each of the test items' label to the target's label. In other words, this slight modification of SINC predicts that (with all other things being equal) induction from *Guga* to *Guba* should be more likely than induction from *Guga* to *Zedo*. Whereas there is evidence supporting this prediction of SINC for young children (Fisher & Sloutsky, 2004), none of the reviewed models of induction can predict or account for these results.

Second, none of the models reviewed by Heit and Hayes (2005) have mechanisms for separating or integrating visual and linguistic information. Recall that SINC specifies these mechanisms and tests them by independently manipulating label, appearance, and (more recently) category information. At the same time, because none of the models reviewed by Heit and Hayes has these mechanisms, it is unclear (a) how these models could separate contribution of linguistic, appearance, and category information and (b) how it is possible to manipulate the three sources independently while maintaining assumptions of each respective model.

Finally, when comparing models of induction to SINC, Heit and Hayes seem to overlook some critical differences in predictions. For example, in reference to recognition data reported by Sloutsky and Fisher (2004a), they wrote that "the Sloman (1993) model is explicitly not a category-based model, so any results indicating that children's judgments are similarity based might be just as compatible with the Sloman model as with SINC" (p. 603).

This statement, however, disregards the important fact that Sloman's model (unlike SINC) does not differentiate either between early and mature induction or between category and label information. Therefore, unlike SINC, it cannot account for (a) differences between children's and adults' recognition accuracy, (b) differences between children's recognition accuracy before and after training, or (c) the differential effects of labels on recognition accuracy of children before and after training (discussed above).

In sum, the attempted conversion of models of inductive reasoning into the "currency" of SINC is problematic. Because, similar to SINC, each of these models has (or can have) a similarity component, the conversion may appear possible. However, because neither of the models differentiates between labels and categories, the conversion ignores one of the most important properties of SINC, thus making the similarity between SINC and converted models rather superficial.

Points of Agreement, Real Limitations of SINC, and Directions for Future Research

Despite the arguments presented above, there are several points of agreement. First, we agree with Heit and Hayes that none of the models of induction, including SINC, has been implemented as a model of recognition and that more work is needed to develop a unified account of categorization and recognition. We also agree that SINC does not differentiate between "projectible" and "nonprojectible" properties. In particular, it has been shown that young children generalize putatively stable properties, such as "has hollow bones," but not transient properties, such as "fell on the floor this morning" (Gelman, 1988). One possibility is that young children understand that these latter properties vary within a category, thus suggesting that children have aggregate representation of categories (Gelman, 1988). Alternatively, it is possible that children differentiate between properties that do and do not vary within individuals, generalizing the latter but not the former. We plan to directly examine this issue in future studies. Finally, we agree that research generated by SINC has been focused on conclusions about individuals, and not about categories. However, there is a principled reason for this: According to SINC, early induction is not category-based and therefore, SINC distinguishes between generalizations to a single versus multiple individuals, but not between generalizations to an individual versus a category.

There are several limitations of SINC that were not mentioned by Heit and Hayes but that should be addressed in future research. First and most important, at this time, SINC does not model mature induction, whereas given that inductive generalization is not limited to young children, it is important to model inductive generalization at different points of development. Second, although SINC assumes flexibility of attentional weights, it is not a model of learning. Therefore, at this time, it can neither model change in the way participants perform induction nor model the transition from early to mature induction. Expanding SINC in the direction of a learning model is an important future goal. Finally, in its current form, SINC does not specify how computed similarity information is stored and retrieved, and therefore, although capable of predicting recognition memory phenomena qualitatively, SINC cannot model recognition. These limitations present interesting and important challenges, and they are to be addressed in future research.

Although more research is needed, SINC and its underlying theory generated new knowledge (a) pointing to the similarity-based mechanism of early induction, (b) revealing how and why labels contribute to similarity and induction early in development, and (c) specifying interrelationships between induction and recognition across points of development.

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