Induction in Children and Adults

Catherine Jane Wilburn (c.j.wilburn@durham.ac.uk)
Department of Psychology, Queen's Campus Durham University,
Thornaby, Stockton-on-Tees, Cleveland TS17 6BH, UK

Aidan Feeney (aidan.feeney@durham.ac.uk)
Department of Psychology, Queen's Campus Durham University,
Thornaby, Stockton-on-Tees, Cleveland TS17 6BH, UK

Abstract

Sloutsky and Fisher (2004 a&b) have demonstrated that children have better recognition memory for the items they generalise to than do adults. Based on this finding, Sloutsky and Fisher (2004 a&b) have claimed that children and adults use different mechanisms for inductive generalizations. They argue that while adults focus on shared category membership, children project properties on the basis of perceptual similarity. Under this view, children's enhanced recognition memory is a by-product of the more detailed processing required by a similarity-based mechanism. The present study proposes an alternative explanation for these findings. We demonstrate that when children are given just 250ms to inspect stimulus items they remain capable of making accurate inferences, but that their subsequent memory for those items decreases significantly. These findings suggest that there are no necessary conclusions to be drawn about the nature of generalization processes from rates of recognition memory.

Keywords: Induction; Reasoning; Learning; Development.

Introduction

Inductive inference by definition is inextricably linked with learning. The ability to extend knowledge from known examples to novel instances is central in allowing children to develop their understanding of the world, and as such underlies learning, category formation and scientific thinking. However, despite its particular importance in childhood, there exists no consensus about how best to explain this early ability.

One idea about how children make inductive inferences is that they use category structure from an early age. One very influential theory of adult category-based induction (Osherson et al., 1990) assumes that reasoners possess a stable hierarchy of categories. According to this similarity-coverage model there are three processes required: similarity calculations, coverage calculations and the generation of the closest super-ordinate category for certain arguments involving a specific conclusion (e.g. a conclusion concerning 'chickens' rather than 'birds').

There is also evidence in the literature on childhood induction that category structure is important in determining the inductive generalizations made by quite young children. For example, in Gelman and Markman's (1986) classic triad tasks, 3 and 4 year old children were asked to examine inductive inferences which pitted category membership against perceptual similarity. In each of the experimental trials children were shown two objects and taught a fact about each. The child's task was to then infer which of these two facts applied to a third object which was perceptually similar to the first item, but shared the same category label as the second. Gelman and Markman found that children as young as 3 years consistently used category membership as a basis for their inductive judgments, even when perceptual similarity would have led to a different conclusion. Subsequent studies have shown the same pattern of inference in children as young as two years of age, (Gelman and Coley, 1990).

However, just as feature-level accounts of adult induction have been proposed (see Sloman, 1993) it is also possible to give accounts of children's generalization based entirely on similarity (see Sloutsky & Fisher, 2004b). Under such an account, children's inductive differences are dependent on the perceptual similarity that holds between the base instance and the target instance, rather than on shared category membership. In a real-world context, perceptual similarity is often confounded with category membership, making the two approaches difficult to definitively separate either on an empirical or a theoretical level (see Heit and Hayes, 2005). For example, although overall children appear to favor category-based induction in the triad task, Sloutsky and Fisher's (2004b) reanalysis of this data showed that only when the same-label (category-based choice) was as similar to the target as the different-label choice could induction be claimed to be performed solely on the basis of shared labels at an above chance level. In the remaining cases where the shared-label choice was markedly different to the target, the results showed a main effect of both perceptual similarity and shared category-membership. This finding nicely illustrates how difficult it can be to disentangle similarity and category-based approaches to induction.

Despite this difficulty, Sloutsky and Fisher (2004 a&b; Fisher & Sloutsky, 2005) have recently described an experimental paradigm that they claim allows them to distinguish between inferences drawn on the basis of perceptual similarity and those drawn on the basis of shared category membership. They claim that participants' memory for presented stimuli may be one observable (and measurable) outcome that is likely to vary depending on the generalisation strategy used. The thinking behind this assumption is as follows; first, if induction is performed on the basis of category membership, then participants must categorise the stimulus items they are asked to consider, creating a 'gist' representation. Studies suggest that when pictures are spontaneously categorised in this way, the lack of perceptual encoding decreases participants' memory for the presented items, (Brainerd, Reyna and Forrest, 2002). In addition, working at the level of categories rather than individuals may also leave participants open to memory distortions such as false recognition of same category lures, (Koutstaal and Schacter, 1997). Hence, if induction is performed in a category-based manner, subsequent memory for the presented items should be poor as the underlying mechanisms do not promote the creation of strong memory traces. Conversely, a similarity-based generalisation strategy actively requires that the perceptual details of items be encoded for the inferences to be made. Therefore, when induction is performed using this strategy, the very nature of the process means that participant's susceptibility to critical lures should be less and their memory for the presented stimuli greater.

On the basis of the considerations outlined above, Sloutsky & Fisher predict that if adults use a category-based strategy and children generalise on the basis of perceptual similarity, then adults should demonstrate poorer recognition memory. In a series of experiments using the induction-then-recognition (ITR) paradigm Sloutsky and Fisher have confirmed this prediction, showing approximately equal rates of correct inductive inferences in eight year olds and adults, but significantly poorer recognition memory for the presented items in the adult data. Additionally, Sloutsky and Fisher also trained young participants to apply a category-based strategy and showed that although their recognition accuracy decreases in the first instance, younger children do not spontaneously reuse such a strategy when subsequently retested (Fisher & Sloutsky, 2005). Not only have Sloutsky and Fisher used these results to argue for fundamentally different generalisation processes in adults and children, they also argue that their secondary developmental results have important implications for our understanding of how inference changes across development, and the age at which assumptions about category structure become manifest.

While the relationship between reasoning and recognition memory is likely to be a fruitful area of study, we will argue that there may be an alternative account of these particular findings. Using a variation of their original methodology, we will attempt to show that Sloutsky & Fisher's recognition memory data say more about differences in visual attention between children and adults than they do about developmental differences in inductive inference.

Attention and the ITR Paradigm

In the ITR paradigm participants are first shown a picture of a cat and told that it has 'beta cells inside its body'. They are then shown 30 further pictures from three different categories (10 cats, 10 birds and 10 bears) and must decide whether each of these animals also has beta cells inside their body. Participants receive yes/no feedback on their responses. In the unannounced recognition memory phase which follows, participants are shown 28 pictures, again drawn from three different categories; 14 cats (7 old, 7 new), 7 bears (all old), and 7 squirrels (all new). The participant's task is then to attempt to discriminate 'old' stimuli (i.e. presented during the induction task phase) from 'new' stimuli (i.e. not presented during the induction task phase).

In Sloutsky & Fisher's studies, correct inductive performance was particularly high, averaging between 75% and 90% in five-year olds and around 90% in adults. The pattern for recognition memory accuracy however is reversed, with children accurately recognising the presented test stimuli and rejecting the critical lures significantly more often than adults.

In this experiment we will examine whether age-related differences in the attention paid to the pictures may account for Sloutsky & Fisher's findings. Simply put, children and adults may use the same category-based strategy for generalisation, but children may have better recognition memory for the pictures because they attend to them more closely, or look at them for longer without necessarily using this additional perceptual information to draw inferences.

We make two main predictions. First, we predict that if children's enhanced recognition memory is a product of greater perceptual engagement with the stimuli then limiting children's inspection times in the induction phase will significantly decrease their subsequent recognition memory. Second, if this enhanced perceptual engagement is unrelated to generalisation strategy and children do use a category-based strategy we should also find that limiting their exposure to the stimuli has no effect on their inductive performance. On the other hand, if children generalise based on perceptual similarity and enhanced recognition memory is a by-product of this, then we would expect significantly poorer recognition memory *and* significantly less accurate generalisations under limited time conditions.

Pre-Test: Determining Exposure Time

In order to decide for how long children and adults should see the stimuli in the limited exposure condition, an experimental pre-test was undertaken. The aim of this pre-test was to determine approximately the minimum inspection time required for accurate identification of the stimulus pictures. As adults are likely to require no less time than children, we tested only children in the pre-test.

Method

Participants 11 children aged 4 to 5 years drawn from local primary schools in the Stockton-on-Tees/Tees Valley area took part in this study.

Materials, Design and Procedure The materials consisted of the 52 colour photographs of animals which were to be used in the main experiment (see Figure 1 for examples). The experiment took the form of a within-participants design, with all participants seeing each of the 52 pictures.

During the pre-test each of the pictures were displayed on screen for either 100ms, 175ms, 250ms or 325ms. The children's task was to attempt to name the animal they had seen on screen. The experimenter then recorded whether the child could provide a name for the animal and whether the name provided was correct. The presentation order of the four timings was randomised as was the order of the 52 photographs.

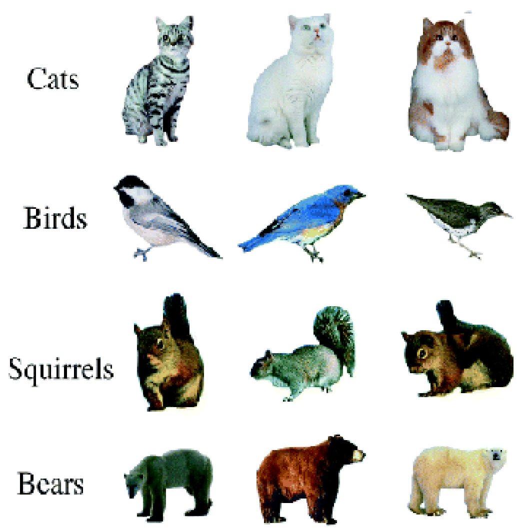

Figure 1: Example of Stimulus Pictures Used

Results

A one-way ANOVA showed a strong main effect of exposure time on children's naming accuracy, $F(3, 40) = 146.67$, $MSE = .13$, $p < .001$. At 100ms mean accuracy was 12% (SD=8.67%), rising to 29% (SD=20.09%) at 175ms, 90% (SD=6.22%) at 250ms, and 97% (SD=5.29%) at 325ms. Tukey HSD post-hoc tests revealed significant differences between all condition pairs (all ps < .01) except between the 250ms and 325ms accuracy scores. These findings suggest that 250ms is the shortest exposure time at which children could consistently identify the animal presented. Accordingly, 250ms was set as the exposure time for the limited condition of the experiment proper.

Experiment: Manipulating Exposure Time

Method

Participants 64 children aged 4 to 5 years (mean age = 60.17 months, SD = 3.44 months) drawn from local primary schools in the Stockton-on-Tees/Tees Valley area, and 64 adults (mean age = 270.7 months, SD = 60.22 months) mainly drawn from the University of Durham, took part in this study.

Materials, Design and Procedure The materials consisted of 52 colour photographs of animals presented on a plain white background, (see Figure 1 for examples). The experiment took the form of a mixed-model design, comparing adult and child groups, across two between-participant conditions; limited time and unlimited time.

In both conditions of the experiment, the participant's task was broken up into two phases; the induction phase and the recognition memory phase. During the induction phase of the experiment, participants were first shown a picture of a cat and told that it had 'beta cells inside its body'. Participants were then shown 30 further pictures, one picture at a time, from three different categories (10 cats, 10 birds and 10 bears). The participant's task was to decide whether each of these presented animals also had beta cells inside their body or not. After each response, participants were given yes/no feedback on their answers, indicating that this property should be projected to the cats but not the bears or birds.

This general procedure remained the same across both the limited and unlimited time condition. The only major difference between conditions related to the amount of time participants had to study each of the stimulus pictures presented. In the ***unlimited time condition*** each of the 30 pictures remained on the computer screen until the participant provided a response, at which point the picture disappeared, verbal feedback was given, and the next picture was displayed. In the ***limited time condition***, each picture remained on screen for 250ms, then the screen went blank until a response was recorded and feedback had been given, at which point the next picture appeared on screen. The subsequent recognition memory task was not mentioned to participants at this stage in the experiment.

The recognition memory phase was presented directly after the induction task. During this phase of the experiment, participants were presented with 35 pictures, again drawn from three different categories; cats (7 old and 7 new), bears (7 old and 7 new) and squirrels (all 7 new). Their task was to decide whether each of these pictures were 'old' (i.e. had been presented during the induction task phase) or 'new' (i.e. had not been presented during the induction task phase). In this section of the experiment all pictures were presented to participants in a self-paced manner, with no feedback given in relation to their responses.

Results

Inductive Accuracy Although the two-way ANOVA (Age group x Induction condition) conducted shows that adults were significantly more accurate than children overall, F(1,124) = 49.94, MSE = 1.13, p< 0.001, scores remained high across the age divide, with all groups recording a mean accuracy rating in excess of 90%, (27 out of 30). Further to this, the ANOVA shows no effect of Induction condition, F(1,124) = 1.56, MSE = 1.13, p = 0.22, nor an interaction between Induction condition and Age group, F(1,124) = .007, MSE = 1.13, p =.93. Although adults are generally more accurate than children, the constraints placed upon participants in the limited time condition had no effect on their ability to perform sound inductive judgments.

Table 1: Mean Inductive Accuracy Scores

	Limited	*Unlimited*	*Total*
Adult	95.42 (3.14)	96.15 (2.82)	95.78 (2.98)
Child	90.94 (4.25)	91.77 (3.78)	91.35 (4.02)
Total	93.18 (4.34)	93.96 (3.98)	93.57 (4.17)

Recognition Memory Accuracy In all conditions both children and adults were more than 90% accurate in their rejection of distracters from an un-presented category (i.e. squirrels). Therefore respondents can be assumed to have been paying attention and taking the task seriously.

In order to analyse participant's recognition memory accuracy, memory sensitivity *A'* scores were calculated. *A'* is a non-parametric analogue of the signal detection statistic *d'* (Snodgrass & Corwin, 1988). It compares the number of 'hits' (correctly identified 'old' pictures) to the number of 'false alarms' (incorrectly recognized 'new' pictures) made by each individual participant. If participants do not discriminate the target items from the critical lures, *A'* is at or below .5. The closer *A'* scores are to 1 the greater the level of discrimination accuracy. Mean *A'* scores for each condition of the design are shown in Table 2.

Table 2: Mean *A'* Recognition Accuracy Scores

		Limited	*Unlimited*
Adult	*Cats*	.5005 (.2195)	.5629 (.2544)
	Bears	.5566 (.2311)	.6211 (.2427)
Child	*Cats*	.4892 (.1795)	.6774 (.1608)
	Bears	.5793 (.2143)	.6897 (.1484)

The results of a 2(Animal: Bear vs. Cat) x 2(Age) x 2(Exposure Time) mixed-model ANOVA contained a marginally significant main effect of Age, F(1,124) = 3.78, MSE =.04, p = .054, such that children's accuracy scores were higher than adults'. The results also show a strong main effect of Induction condition, F(1,124) = 18.11, MSE = .04, p < .001, with *A'* scores decreasing significantly in the limited time condition.

Of most interest is the marginally significant interaction between Age and Exposure Time, F(1, 124) = 2.95, MSE = .04, p = .09. The means involved in this interaction are displayed in Figure 2 where it may be seen that in the unlimited time condition children discriminate well between target items and critical lures, with an overall *A'* score of .6903. In the same condition, adults' discrimination accuracy, although above chance, is significantly poorer than that of the children, (*A'* = .5912). These finding replicate those of Sloutsky & Fisher (2004 a&b).

In the limited condition however, although both adults' and children's recognition accuracy is significantly affected by the exposure time constraint, this effect is much greater in the children's scores. In this condition, the adults' overall *A'* score is .5360. Although this is a minor decrease, an independent samples t tests show that the difference due to Exposure Time is not statistically significant, t(62) = -1.243; p=.219.

The children's *A'* scores on the other hand fall dramatically in this condition, with *A'* being reduced to just above the 0.5 chance level (*A'* = .5274). Planned comparisons showed that *A'* scores for children in the unlimited time condition were significantly higher than *A'* scores in each of the other three conditions (all ps < .05). There were no other significant differences between conditions. These findings suggest that although an age difference in recognition memory is apparent when participants are given unlimited time to inspect the stimuli, this effect of age disappears when inspection time is limited.

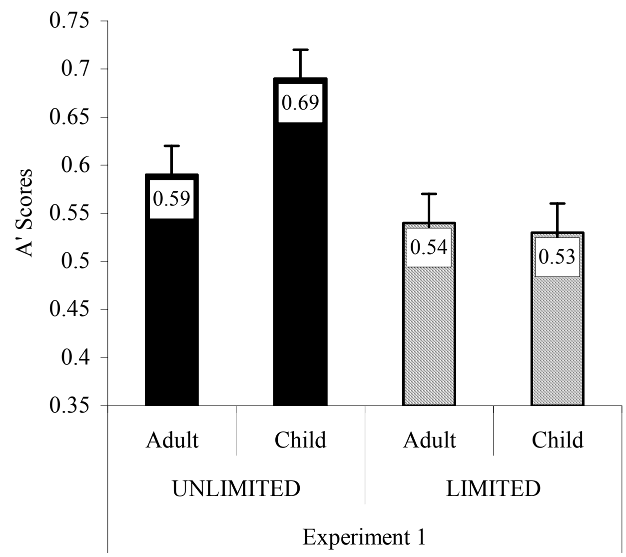

Figure 2: Mean *A'* Recognition Accuracy Scores

Finally, the ANOVA also showed a significant main effect of Animal. Recognition accuracy for Bears (*A'* = .61) was significantly higher than for Cats (mean *A'* =. 56), F(1,124) = 3.93, MSE = .05, p < .05.

Discussion

In this experiment the conditions of stimulus exposure were specifically designed to be unfavorable to the use of a similarity-based strategy. By reducing children's stimulus exposure to just a quarter of a second it was assumed that participants would be unable to extract sufficient featural information on which to base a similarity-based judgment. As expected, this manipulation severely affected children's recognition memory, reducing children's *A'* scores to a comparable level with those shown by adults in both the limited and unlimited conditions. However, despite this reduction in recognition memory, children's inductive accuracy was unaffected by the manipulation. This suggests that although children's enhanced recognition accuracy does stem from a greater perceptual engagement with the stimulus pictures as Sloutsky and Fisher (2004b) might suggest, this heightened perceptual engagement need not be related to their generalisation strategy. Enhanced recognition in children does not necessarily imply a similarity-based mechanism.

Although the results of Experiment 1 support our alternative attentional account of Sloutsky and Fisher's (2004 a&b) results, our finding of significantly higher recognition accuracy scores for bears than for cats may be problematic for the attentional account. The effect is that participants have better memory for items they did not generalize to than for items to which they did. Our alternative explanation is based on the assumption that children perform generalisations in a category-based manner and that enhanced recognition memory is the product of greater perceptual engagement. Accordingly, we might expect that if any differences between the stimulus sets were observed, this difference should favor the items to which the property was generalised, as these stimuli might be expected to receive more attention.

However, it is also possible that there was greater similarity between our sample of cats than between our sample of bears thus making it harder to discriminate 'old' from 'new' cats. To test this possibility we carried out an experimental post-test of our stimuli.

Post-Test

Method

Participants 12 adults aged between 17 and 61 years (Mean age = 42.9 years, SD = 14.7 years) took part in this study. They were drawn from the Stockton-on-Tees/Tees Valley area.

Materials, Design and Procedure The materials consisted of the 14 cat and 14 bear pictures used in the recognition memory phase of Experiment 1, (7 old cats, 7 new cats, 7 old bears, 7 new bears). In each of the cat and bear stimulus sets, 'old' and 'new' pictures were paired up to create all of the 49 possible combinations, so every 'new' cat picture was paired with every 'old' cat picture and so on.

The pairs were presented to participants as Microsoft PowerPoint slides which they could work through in a self-paced manner. Participants task was to rate the similarity of the two pictures in each pair, on a 9-point Likert scale, ranging from 'Very Similar' to 'Not at all Similar'. Both the ordering of the two pictures within each pair and the ordering of the pairs in general was randomised to avoid any order effects occurring either within or across individual similarity ratings.

Results and Discussion

Participants rated 'old' and 'new' cat pictures (Mean = 4.56, SD = 0.97) as significantly more similar than 'old' and 'new' bear pairings, (Mean = 5.04, SD = 0.91), $t(11) = 3.08$, $MSE = .16$, $p < .05$. This suggests that the greater recognition memory for 'bear' pictures shown in Experiment 1 was most likely due to the relatively high discriminability of these items.

General Discussion

We observed a clear effect of limiting exposure time on children's memory performance, with recognition accuracy substantially decreased in the reduced exposure conditions. At the same time as reducing memory performance however, the limited exposure condition had no effect on children's inductive accuracy, with 5 year olds still being capable of near perfect generalizations. These findings are therefore consistent with the alternative attentional hypothesis we have put forward to account for Sloutsky and Fisher's (2004 a&b) original findings. Although children and adults attend to the objects they are asked to reason about differently, with children seeming to pay greater attention to the stimuli, both groups appear to apply similar generalisation strategies. That is, both groups make accurate generalizations in conditions unfavorable to the use of a similarity-based mechanism.

One possible counter-argument to this interpretation is that participants may apply some restricted version of a similarity-based approach utilising a limited number of features across which to make comparison judgments. Although this is possible, it should be remembered that we selected an exposure time that only just gave participants sufficient time to categorise the stimuli. As similarity-based process might be expected to take longer than a category-based process, (for a recent review of the relevant empirical evidence see Brainerd and Reyna, 2005), we think it unlikely that a feature-matching strategy could be executed to produce accurate inferences in the time available to participants.

The fact that our results do not definitively show which strategy participants used when making their inductive judgments also means it may be the case that generalisations made in the limited time condition are the product of a different strategy to those of the unlimited time condition. It may be that children of this age are capable of a number of overlapping and eventually converging inductive strategies. This co-existence of more and less sophisticated reasoning processes has been argued in other areas of cognitive development such as the acquisition of mathematic skills, where current thinking suggests that rather than alternating between problem-solving strategies in a step-like manner (Case, 1992), children are capable of a number of different strategies (Siegler, 1999) and switch between them both within and between tasks. Applying this view to the present data, it may be the case that when children have the option of choosing between inductive strategies i.e. in the unlimited time conditions, by preference they use a time-heavy similarity-based strategy on which to base their inductive inferences. However, in the limited time conditions when this strategy is no longer viable children of this age are equally capable of using a category-based strategy in order to draw their inductive judgments. This explanation is supported by the ease with which children picked up a category-based strategy in Sloutsky and Fisher's (2004 a&b) second training study. Heit and Hayes (2004) have suggested that rather than 'teaching' the children a 'new' induction strategy, Sloutsky and Fisher may simply have directed them towards the use of the category-based approach already within their repertoire.

Even allowing for the objections outlined, the fact that our results are so consistent with the alternative attentional hypothesis means that although multiple strategies may be possible, at the very least there are no necessary conclusions to be drawn about developmental differences underlying inductive inference from recognition memory data.

As outlined in the introduction to this study, Fisher and Sloutsky (2004) have claimed that induction is a changing developmental process, which does not result in the ability to apply category concepts to inductive inference until between the ages of 7 and 11 years. The present study suggests that this is not the case. Regardless of whether children performed category-based induction in both the limited and unlimited conditions, or whether the use of this strategy was restricted to the limited condition only, children in this study, as young as 4 years of age, spontaneously used a category-based strategy.

As it concerns very young children, this finding is problematic for Fisher and Sloutsky's (2004) claims about a developmental trajectory as well as their more general developmental argument. The patterns in the memory data can more parsimoniously be explained by differences in attention than they are by positing different generalisation strategies in children and adults. In other words, children may remember more simply because they pay more attention, and not because they think differently.

Acknowledgements

The experiments described were carried out by the first author under the supervision of the second as partial fulfillment of the requirements for an M.A. in Research Methods at Durham University. The first author is supported by the Economic and Social Research Council; grant number PTA-031-2004-00339.

We would like to thank all the teachers and students who assisted with this study. Thanks also to Vladimir Sloutsky and Anna Fisher for sending us their original stimulus materials.

References

Brainerd, C.J., Reyna, V.F., and Forrest, T.J. (2002). Are young children susceptible to the false-memory illusion? *Child Development, 73*, 1363-1377.

Brainerd, C.J., and Reyna, V.F. (2005). *The Science of False Memory.* Oxford University Press: Oxford.

Case, R. (1992). *The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Fisher, A.V., and Sloutsky, V.M. (2004). When induction meets memory: Evidence for a gradual transition from similarity-based to category-based induction. *Child Development, 76*, 583-597.

Gelman, S.A. (2003). *The Essential Child*. Oxford University Press: Oxford.

Gelman, S.A. and Coley, J. (1990). The importance of knowing a dodo is a bird: Categories and inferences in 2-year-old children. *Developmental Psychology, 26,* 796-804.

Gelman, S. A., and Markman, E. M. (1986). Categories and induction in young children. *Cognition, 23*, 183-209.

Hayes, B.K., and Heit, E. (2004). Why learning and development can lead to poorer recognition memory. *Trends in Cognitive Sciences, 8*, 337-339.

Heit, E., and Hayes, B.K. (2004). Relations between categorization, induction, recognition, and similarity. *Journal of Experimental Psychology: General, 134*, 596-605.

Koutstaal, W., and Schacter, D.L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language, 37*, 555-583.

Madole, K.L., and Oakes, L. (1999). Making sense of infant categorization: Stable processes and changing representations. *Developmental Review, 19*, 263-296.

Osherson, D.N., Smith, E.E., Wilkie, O., López, A., and Shafir, E. (1990). Category-based Induction. *Psychological Review, 97,* 185-200.

Sielger, R.S. (1999). Strategic development. *Trends in Cognitive Sciences,* 3, 430-435.

Sloutsky, V.M., and Fisher, A.V. (2004a). When development and learning decrease memory: Evidence against category-based induction in children. *Psychological Science, 15*, 553-558.

Sloutsky, V.M., and Fisher, A.V. (2004b). Induction and categorization in young children: A similarity-based model. *Journal of Experimental Psychology: General, 133*, 166-188.

Snodgrass, J.G., and Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to Dementia and Amnesia. *Journal of Experimental Psychology: General*, *117*, 34-50.