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Distinguishing between Category-based and Similarity-based Induction

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Abstract

Performing inductive generalizations is critical for learning, yet there is much debate regarding the mechanisms underlying this ability. One view posits that similarity-based induction, utilizing perceptual features, may allow for increased encoding and higher memory accuracy on recognition tests. While category-based induction, utilizing semantic information, may result in limiting encoding of perceptual detail, thus resulting in decreased memory accuracy. In Experiment 1, we attempted to impair spontaneous categorization by presenting a second Working Memory load task. In Experiment 2, we attempted to impair perceptual processing by introducing a second Visual Search task. Results indicate that adult participants can rely on either mechanism when performing induction.

Keywords: Induction; Learning; Memory.

Introduction

The ability to generalize from the known to novel is a critical aspect of cognition – this ability allows expanding knowledge to new situations. At the same time, the learner may not know how far new knowledge can be expanded outside of the learning situation. Suppose that one learned that adenosine promotes myelination in the brain of the Capuchin monkey. Should this knowledge be generalized to New World monkeys, all monkeys, all primates, or all mammals? One way of generalizing knowledge is by identifying a common category that licenses such generalization. For example, one may decide that MONKEY is such a category and generalize knowledge to all monkeys. However, while knowledge of categories is useful, it is not necessary for inductive generalization. For example, one may decide that animals share a property to the extent their similarity exceeds some criterial value.

The latter mechanism seems to be a good candidate for generalization early in development, whereas the former could be a product of development. However, despite the fact that inductive generalization exhibits early onset (Baldwin, Markman, & Melartin, 1993; Gelman & Markman, 1986; Sloutsky, Lo, & Fisher, 2001; Welder & Graham, 2001), the mechanisms underlying early induction are hotly debated.

According to the naïve theory approach (see Murphy, 2002, for a review) induction is a two-step process: children first identify encountered entities as members of categories, and, if entities belong to the same category (say, the same natural kind), then infer that these entities share many properties. The inference is licensed by children's assumptions that members of some categories (such as, for example, natural kinds) share many properties. Given that children are more likely to know basic-level categories (e.g., MONKEY) than superordinate categories (e.g., MAMMAL), they are more likely to generalize properties within basic-level categories.

According to another position (i.e., the similarity view), induction is a generalization process, and young children generalize on the basis of multiple commonalities, or similarities, among presented entities (e.g., Jones & Smith, 2002; McClelland & Rogers, 2003; Sloutsky, Fisher, & Lo, 2001; Sloutsky, 2003, Sloutsky & Fisher, 2004a, 2004b). This view does not attribute conceptual assumptions to young children.

In an attempt to address these issues, Sloutsky and Fisher (2004b; Fisher & Sloutsky, 2005) introduced Induction-then-Recognition (ITR) paradigm. The idea is based on the following reasoning. There is a well-known "level-of-processing effect" – deeper semantic processing facilitates correct recognition of presented items, increasing the proportion of "hits" (Craik & Lockhart, 1972; Craik & Tulving, 1975). At the same time, deeper processing also results in higher levels of memory intrusions – false recognition of non-presented "critical lures" of semantically associated or categorically related items (e.g., Koutstaal & Schacter, 1997; Rhodes & Anastasi, 2000; Thapar & McDermott, 2001). Due to elevated levels of false alarms, the net result of deep semantic processing on recognition accuracy (i.e., Hits – False Alarms) is negative. At the same time, it is known that focusing on perceptual details of pictorially presented information leads to more accurate recognition (Marks, 1991) – although hits might be slightly lower, false alarms are significantly lower than under deep semantic processing. Therefore, these memory findings suggest that categorization (which is a variant of deeper semantic processing) would result in a higher level of memory intrusions and thus in lower recognition accuracy than shallow perceptual processing (see also Brainerd, Reyna, & Forrest, 2002, for related arguments).

Thus, a memory test administered after an induction task may reveal differential encoding of information during induction: if participants perform category-based induction, they should be engaged in deep semantic processing, and therefore exhibit low discrimination of studied items from critical lures during a memory test (compared to a no-induction baseline condition). On the other hand, if participants perform similarity-based induction, they should be engaged in shallow perceptual processing, and as a result their memory accuracy should not decrease compared to the baseline. Because, unlike adults, young children were expected to perform similarity-based induction, this reasoning led to a nontrivial prediction that after performing induction, young children may exhibit greater memory accuracy (i.e., have fewer false alarms) than adults.

These predictions have received empirical support: the pattern of results reported by Sloutsky and Fisher (2004a; 2004b; Fisher & Sloutsky, 2005) indicated that while adults perform category-based induction, young children perform similarity-based induction. In particular, after performing inductive generalizations about members of familiar animal categories (i.e., cats, bears, and birds), adults' memory accuracy attenuated markedly compared to the no-induction baseline, and, these effects of induction were robust across a wide range of animal categories (Fisher & Sloutsky, 2004). At the same time, young children were accurate in both the baseline and induction conditions, exhibiting greater accuracy in the induction condition than adults.

Although these findings are compatible with the idea of different mechanisms of induction across development (i.e., similarity-based early induction and category-based mature induction), a number of alternative explanations have been proposed. In particular, Wilburn and Feeney (2008) and Hayes, McKinnon, & Sweller (2008) suggested that the mechanism of induction does not change across development (with induction being category-based) and the higher memory accuracy of children simply reflects their inability to filter out irrelevant perceptual information. In other words, whereas adults process primarily category information, young children cannot focus efficiently, and, as a result, they process both category and perceptual information. Although there are several phenomena that this idea cannot explain (see Sloutsky, 2008), we deemed it necessary to address the issue directly.

To do so, we created a new paradigm to examine the issue. The underlying idea is to selectively impair either categorical or perceptual processing and to examine induction and memory performance. If participants can rely on either information (which we believe is the case with adults), then neither manipulation should have an effect on induction. If participants rely primarily on perceptual information (which we believe is the case with children), then impairing perceptual processing should impair induction.

Each manipulation should also have a different effect on memory. Impairing categorical processing should force participants to process items perceptually, thus potentially increasing memory accuracy after performing induction. At the same time, impairing perceptual processing should force participants to process items categorically, thus potentially decreasing memory accuracy.

In research reported here, we tested this paradigm with adults. The main idea is to introduce a second task when participants perform induction. To impair categorical processing, we introduce a working memory task, whereas to impair perceptual processing, we introduce a visual search task.

In what follows, we report two experiments: In Experiment 1, the second task is a working memory task, whereas in Experiment 2, the second task is a visual search task. We compare performance on these experiments with performance reported by Sloutsky and Fisher (2004), when no secondary tasks were introduced.

Experiment 1: Induction with Working Memory Load

The experiment was a replication of Sloutsky and Fisher (2004b) ITR paradigm with one difference: during the study phase participants were presented with a second task, whose goal was to increase working memory load.

Method

Participants. Sixty-two introductory psychology students participated in the experiment for class credit. Twenty-six participants were excluded due to low accuracy on check trials in the recognition portion of the experiment.

Materials, Design and Procedure. Visual Stimuli consisted of 44 color photographs of animals on white backgrounds (see Figure 1 for examples). Auditory Stimuli consisted of ten familiar words (e.g., one, two, three, four, five, six, seven, eight, nine, ten) presented through headphones between 68-72 dB.

Similar to Sloutsky and Fisher (2004b), the experiment included two between-subjects conditions: Memory and Induction. In both conditions, the experiment was divided into two phases: the study phase and the recognition phase.

During the study phase of both conditions, participants received a working memory (WM) task. For the WM task, participants were initially presented with five randomly selected Auditory Stimuli and asked to listen for one of the words to be played more than one time on each of the subsequent study phase trials. At the end of each trial participants were asked if one of the words had been repeated and were provided with Yes/No feedback.

The primary task of interest differed across the conditions: in the Induction condition participants were asked to generalize properties and in the Memory condition, they were asked to remember the items as accurately as possible.

Study Phase: Induction Condition. During the study phase, participants were presented with 30 pictures of animals, one at a time, in a random order. The animals were selected from 3 categories: 10 bears, 10 birds, and 10 cats. The pictures were presented centrally on a 22" wide screen monitor for 2750 ms each. After being introduced to the WM task, participants were then shown a picture of a cat and were told the cat had "beta cells in its blood." Throughout the study phase of the Induction condition, participants were first asked after each trial whether one of the words had been repeated and Yes/No feedback was provided. They were then asked to decide whether each presented animal also had beta cells. Yes/No feedback was provided indicating that only cats had beta cells.

Study Phase: Memory Condition. The Memory condition was similar to the Induction condition, with a single difference: instead of performing an induction task, participants were asked to remember the items as accurately as possible. They were also warned about the upcoming memory test.

Recognition Phase. The recognition phase was identical across both conditions. The recognition phase immediately followed the study phase. During recognition, participants were presented with 28 images, 14 of which had been presented in the study phase and 14 of which were new images. Participants were instructed to determine whether each image had been presented during the study phase and neither feedback nor secondary task was given.

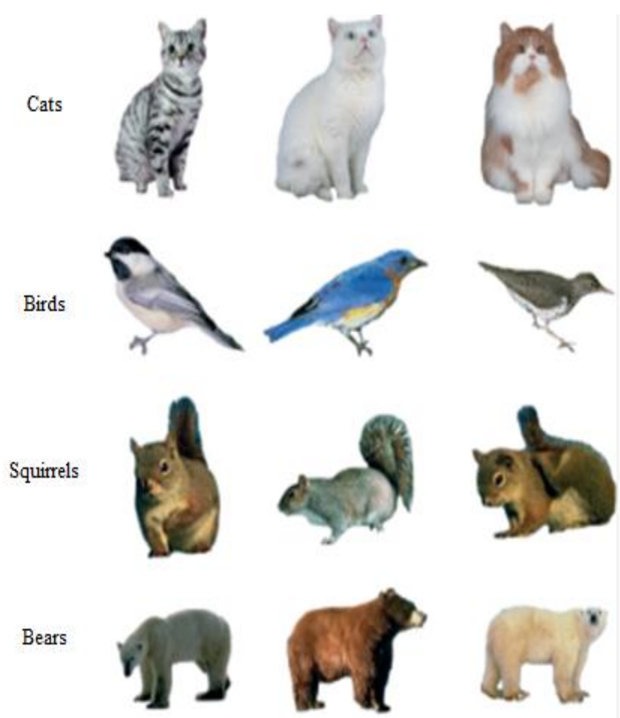

Figure 1: Examples of Visual Stimuli

Results and Discussion

In this experiment, it was expected that spontaneous categorization would be hindered due to increased working memory load. Therefore, compared to a single task condition in Sloutsky and Fisher (2004b), the dual task condition may increase the overall task difficulty thus attenuating recognition accuracy in the Memory condition. At the same time, it may block categorization, thus increasing recognition accuracy in the Induction condition. The average rate of correct induction was over 98%, compared to over 75% induction accuracy in Sloutsky and Fisher (2004b).

To analyze recognition memory accuracy, Hit and False Alarm (FA) rates were calculated (see Table 1). Also in the Table are Hit and FA rates from Sloutsky and Fisher (2004b). Because these researchers did not use a secondary WM task, we will refer to their experiment as "Baseline".

To further examine the ability to discriminate old items from critical lures, we computed memory sensitivity *A′* scores. *A′* is a nonparametric analogue of the signal detection statistic d' (Snodgrass & Corwin, 1988; Wickens, 2002). If participants do not discriminate old items from critical lures, *A′* is at or below .5. The greater the discrimination accuracy, the closer *A′* is to 1. *A′* scores for Experiment 1 are presented in Figure 2 alongside *A′* scores for Experiment 2, as well as the results of the Sloutsky and Fisher (2004b) Baseline data.

Data in the figure were submitted to a 2 (Experiment: Working Memory vs. Baseline) by 2 (Condition: Induction vs. Memory) ANOVA. The analysis revealed a significant interaction between experiment and condition, F (1, 80) = 5.58, p= .02 as well as a significant main effect of condition, F (1, 80) = 14.38, p < .000. Independent samples t-tests indicated that memory accuracy in the Memory condition of the current experiment was lower than that in Sloutsky and Fisher (2004b), t (35) = -2.23, p < .05. At the same time the opposite was true for the Induction condition, in which the WM load of the current experiment resulted in marginally higher memory accuracy than a single task induction accuracy reported in Sloutsky and Fisher (2004b), t (45) = 1.54, p = .13.

Table 1
Mean Proportions of Hits and False Alarms (FA) and Mean Accuracy

Condition	Hits	FA	Accuracy (hits-FA)
WM-Ind	.78 (.16)	.59 (.26)	.19
WM-Mem	.77 (.14)	.52 (.22)	.24
*S&F-Ind	.83 (.20)	.76 (.25)	.07
*S&F-Mem	.89 (.10)	.47 (.31)	.42

Note. WM – working memory; *S&F – Sloutsky & Fisher (2004b); Standard deviations are in parentheses.

Taken together results of Experiment 1 indicate that impairing categorization by introducing a secondary WM task does not affect induction accuracy, but it does affect memory accuracy. Most importantly, memory accuracy in the Induction condition increased somewhat, compared to the memory accuracy in the single-task Induction, which was not the case for the Memory condition. These results confirm that if categorization is impaired, adults can rely on perceptual information to perform induction. In Experiment 2, we attempted to impair participants' perceptual processing.

Experiment 2: Induction with Perceptual Load

The experiment was similar to Experiment 1, with one critical difference: the second task was a visual search task, whose goal was to impair perceptual processing rather than categorization.

Method

Participants. Fifty-six introductory psychology students participated in the experiment for class credit. Thirty participants were excluded due to low accuracy on check trials in the recognition portion of the experiment.

Materials, Design and Procedure. Visual Stimuli consisted of the same 44 color photographs used in Experiment 1. Visual Search Stimuli consisted of a total of 16 red or black "+" and "o" symbols. These stimuli were presented in random sequence by Rapid Serial Visual Presentation, with items being displayed for 250 ms each and having an inter stimulus interval of 250 ms. Visual Search stimuli were presented in the upper right hand corner of the screen with eccentricity of approximately 23° visual angle and subtending approximately 1.4° of visual angle. Experiments were conducted on a Dell Optiplex 790 computer and were programmed in E-Prime Professional 2.0 software.

Similar to Experiment 1, this experiment included two between-subjects conditions: Memory and Induction. Also, similar to Experiment 1, the two conditions differed only in the Study phase, while having identical Recognition phase.
The Study phase of each condition was similar to the respective condition of Experiment 1, with a single difference. The second task in Experiment 2 was a Visual Search (VS) task.

During the study phase of both conditions, participants were presented with Visual Search stimuli in the upper right corner of the monitor and asked to watch for red "+" signs on each of the subsequent study phase trials. The Visual Search stimuli preceded the onset of animal pictures by 3000 ms and continued 2000 ms after the picture of the animal disappeared. The study phase consisted of the same 30 pictures of animals as in Experiment 1 and were presented centrally on a 22" wide screen monitor for 2750 ms each. After each study phase trial, participants were first asked whether a red "+" sign had been presented. In both conditions, participants were instructed to not look directly at the animal pictures. Participants' eye gaze was monitored by an experimenter and verbal corrective feedback was provided. Immediately following the last Visual Search stimuli on each trial, participants were asked whether they had seen any red "+" signs and Yes/No feedback was provided.

Study Phase: Induction Condition. During the Induction Condition, participants were first asked whether they had seen any red "+" signs and were provided with Yes/No feedback. They were then asked whether the animal had beta cells and were given Yes/No feedback indicating that only cats have beta cells.

Study Phase: Memory Condition. The Memory condition was similar to the Induction condition, with a single difference: instead of performing an induction task, participants were asked to remember the items as accurately as possible.

Recognition Phase. The recognition phase was similar to that in Experiment 1: in the Memory condition participants were told in advance about the upcoming recognition phase, whereas in the Induction condition, no advanced warnings about upcoming recognition were given. The recognition phase immediately followed the study phase. During recognition, participants were presented with the same 28 images that were presented in Experiment 1, 14 images had been presented in the study phase and 14 were new images. Participants were instructed to determine whether each image had been presented during the study phase and neither feedback nor secondary task was given.

Results and Discussion

In this experiment, it was expected that perceptual processing would be impaired due to the demands of the Visual Search task. The average rate of correct induction was over 94%, compared to over 75% induction accuracy in Sloutsky and Fisher (2004b).

Hit and false alarm rates are presented in Table 2 and *A′* scores for Experiment 2 are presented in Figure 2 alongside *A′* scores for Experiment 1, as well as the results of the Sloutsky and Fisher (2004b) Baseline data. Hit and false alarm percentages for Experiments 1 and 2, as well as the Sloutsky and Fisher Baseline percentages are presented by condition in Table 3.

Table 2
Mean Proportions of Hits and False Alarms (FA) and Mean Accuracy

Condition	Hits	FA	Accuracy (hits-FA)
VS-Ind	.71 (.20)	.59 (.28)	.12
VS-Mem	.58 (.22)	.39 (.23)	.18
*S&F-Ind	.83 (.20)	.76 (.25)	.07
*S&F-Mem	.89 (.10)	.47 (.31)	.42

Note. VS – Visual Search; *S&F – Sloutsky & Fisher (2004b); Standard deviations are in parentheses.

A′ scores shown in Figure 2 were submitted to a 2 (Experiment: Visual Search vs. Baseline) by 2 (Condition: Induction vs. Memory) ANOVA. The analysis revealed a significant interaction, $F(1, 70) = 4.65$, $p < .05$, as well as a main effect for condition, $F(1, 70) = 10.08$, $p = .002$. Furthermore, two tailed independent samples t-tests indicated a significant decrease in memory accuracy in the Memory condition of Experiment 2 compared to Sloutsky and Fisher (2004b), $t(29) = -2.38$, $p < .05$; but not in the Induction condition $t(41) = .60$, $p = .55$.

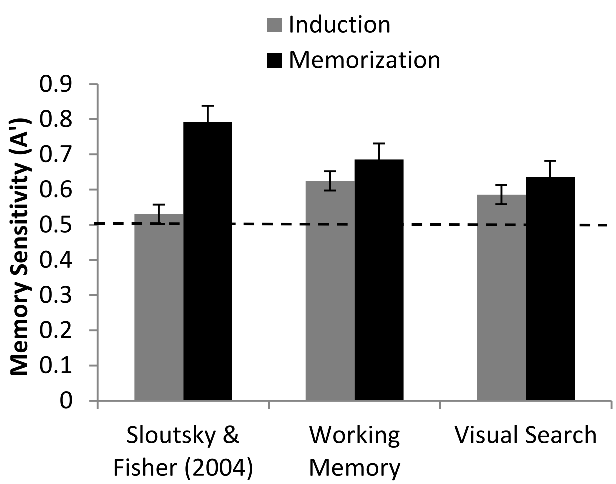

Figure 2. Memory Sensitivity scores (A') across experimental conditions. The dashed line represents the point of no sensitivity. Error bars show standard errors of the mean.

Table 3
Mean Proportions of Hits and False Alarms (FA) and Mean Accuracy

Condition	Hits	FA	Accuracy (hits-FA)
WM-Ind	.78 (.16)	.59 (.26)	.19
WM-Mem	.77 (.14)	.52 (.22)	.24
VS-Ind	.71 (.20)	.59 (.28)	.12
VS-Mem	.58 (.22)	.39 (.23)	.18
*S&F-Ind	.83 (.20)	.76 (.25)	.07
*S&F-Mem	.89 (.10)	.47 (.31)	.42

Note. Standard deviations are in parentheses.
*Indicates data from Sloutsky & Fisher (2004).

Overall, results of Experiment 2 indicate that impairing perceptual processing does not impair inductive inference in adults, while significantly impairing recognition accuracy in the memory condition.

General Discussion

The two reported experiments introduce and test a new paradigm for studying the mechanism of induction. Experiment 1, attempts to impair semantic categorization by introducing a secondary Working Memory task, while Experiment 2 attempts to impair perceptual processing by introducing a secondary Visual Search task. Results indicate that whereas participants were able to perform inductive inference in both conditions, each manipulation somewhat differently affected recognition accuracy in the Memory and Induction conditions.

First, both tasks impaired recognition accuracy in the Memory condition compared to a single task Baseline, perhaps more so in the Visual Search than in the WM condition. Note that when Visual Search was the secondary task, recognition memory in the Induction condition (similar to the Baseline) was not different from 0.5 ($p > .12$), which indicates no discrimination between old items and critical lures. At the same time, when working memory was the secondary task, recognition memory in the Induction condition was above 0.5 ($p < .05$) In addition, the WM task (whose goal was to block semantic categorization) increased somewhat memory accuracy in the Induction condition.

The reported results support the idea that adults may perform inductive inference by relying on either conceptual or perceptual information. In future research, we plan to present these tasks to children. If mechanisms of induction in children are equivalent to those of adults, then, similar to adults, children should be able to perform induction in either condition (although their memory accuracy may attenuate due to increased task demands). In contrast, if children rely on perceptual (but not conceptual) processing when performing induction, their induction performance should drop in the Visual Search, but not in the WM condition. We believe that the new paradigm presented here can address these issues.

Acknowledgments

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