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Peculiarity doesn't trump ordinarity: On recognition memory for exceptions to the category rule

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Abstract

While exceptions to a regularity might be rare, categories that have exceptions are not. Previous studies on learning categories that have exceptions suggested special status of exceptional items in memory (e.g. Palmeri & Nosofsky, 1995, Sakamoto and Love, 2004). However, this might be true only for a special kind of exceptions – those that call for forming complex binding structures, and could be learned only if they are fully memorized. In the two experiments in this study, we show that memory for exceptions is not better than memory for regular category members (Experiment 1). On the contrary, both children and adults had better memory for the features of regular items (Experiment 2). In addition, adults, but not 4-year-olds, showed better memory for the rule than for probabilistic features. The overall results challenge the idea of the special status of exceptions in memory.

Keywords: rule-plus-exception; differential memory; category structure

Introduction

An exception is a case to which a rule or a general statement does not apply. Tomatoes are an exception to the category of vegetables, penguins are an exception to the category of birds, bats to the category of mammals, and the verb "cut" (since it does not change its form) is an exception to the rule of tense formation. While exceptions may be of various kinds, what is common for all of them is that they violate our expectations about how something (or someone) should behave, what it should look like, where it should belong, as well as other expectations that are based on our previous knowledge. Therefore, understanding of how we learn about and how we represent those rare, deviant cases is an interesting problem for the theories of category learning.

A common assumption underlying models that aimed to explain how we learn and represent exceptions, is that exceptions have a privileged memory status. Work in the schema literature contrasting memory for schema-consistent (i.e., in accord with expectations) and schema-inconsistent information, demonstrated that schema-inconsistent information is remembered better (for meta-analysis see, Rojahn & Pettigrew, 1992). It has been argued that the schema-inconsistent memory advantage (i.e. tendency to false alarm to schema-consistent information) may be a specific case of a general advantage for distinctive information. Similar to the "von Restorff effect", where there is a recall advantage for a single word in uppercase in a list of lowercase words (von Restorff, 1933), it is expected that once expectations about an event or category structure are formed, the deviant item should attract more attention and thus have stronger memory trace.

Another account that aimed to explain inconsistent information memory advantage focused on the difference in the depth of processing. Since deviant items may be more difficult to process than regular items (Fabiani & Donchin, 1995; Graesser, 1981), they tend to receive more study time (Stern, Marrs, Millar, & Cole, 1984), and this leads to better memory. When study time is limited, there should be no advantage, or the pattern may even be reversed (Metcalfe, 2002; Thiede & Dunlosky, 1999).

Studies in category learning also support the claim of better memory for exceptions. In an old-new recognition task, Palmeri and Nosofsky (1995) tested participants' memory for two newly learned categories. In both categories, the majority of items could be categorized based on a simple (single-dimension) rule, but there was one exception item which respected the rule of the contrasting category. The main result of their study was that participants showed superior recognition memory for those items that were exceptions to the rule. These findings were in accordance with the prediction of the RULEX (rule-plus-exception) model of classification learning (Nosofsky, Palmeri and McKinley, 1994). According to this model, people tend to form simple logical rules to define categories, and if not all the members of the category follow the formed rule, those occasional exceptions are stored in memory. Thus, regular members of the category and exceptions are supposed to be learned using two independent mechanisms. Based on RULEX, the role of memory processes in categorization of the regular category items should be minimal, which stands in high contrast with purely memory based representation of the exception.

Similar to RULEX, SUSTAIN (Love, Medin, Gureckis, 2004) model assumes formation of specialized representations (clusters) for exceptions that violate initially formed representation (cluster), and predicts that differential storage of exceptions makes them more distinctive in memory. The main difference between the two models lies in flexibility. SUSTAIN emphasizes the need for a flexible search of a given category structure, and allows for clusters to be of different nature (e.g. rules, prototypes, attractors), all depending on the (sub)structure of the category and the task goals. That way, in addition to successfully predicting memory advantage for exceptions, SUSTAIN is sensitive to effects of structure saliency (e.g. frequency effects), familiarity effects (differentiating between old and new rule-following items) or unsupervised learning, which are all problematic for RULEX to account for (Sakamoto & Love, 2004).

Despite described differences, both RULEX and SUSTAIN are in accord with the previous categorization and schema literature regarding (a) memory advantage for rule-violating exceptions, (b) deeper (at a greater detail) processing of exceptions compared to regular category members (Loftus & Mackworth, 1978) and (c) attribution of memory advantage for exceptions to differential attention during encoding (von Restorff, 1933).

Nature of the exceptions

It is important to note here that previous studies (e.g. Palmeri & Nosofsky, 1995, Sakamoto and Love, 2004; Davis, Love, & Preston, 2012) focused primarily on a specific type of exceptions – exceptions that violate prior knowledge expectations by respecting the contrasting category rule. Those exceptions could not be learned by relying on a rule, nor by relying on the similarity with the other category members. In order to be successfully categorized they required forming complex binding structures. Thus, it is unclear whether the better memory for exceptions results from exceptions being rare and violating the prior knowledge expectation (in this case, the category rule), or because of their peculiar structure.

Developmental differences

All hypothesized solutions for learning and representing exceptions were formulated with an adult in mind. Little is known about how exceptions may be learned and represented early in development.

Both RULEX and SUSTAIN assume engagement of selective attention and (to different extent) optimization of memory resources during category learning. However, previous studies suggest that in contrast to adults and older children, who optimize their attention to category and task relevant dimensions, young children tend to allocate attention to both relevant and irrelevant information (Sloutsky, 2010; Deng & Sloutsky, 2016). The developmental differences in attention allocation during category learning (i.e., selective vs. distributed) have important consequences on what is remembered about categories. While selective attention results in better memory for information that is particularly useful for distinguishing the categories (e.g. rule features), distributed attention results in all information, relevant and relevant, being remembered equally well (Deng & Sloutsky, 2016). Thus, if difference in recognition memory for regular category members and exceptions arise from optimization and selectivity, as previously suggested, no difference in memory for regular and exceptional items should be expected for young children.

Current study

In the two experiments reported here, we tested the generalizability of the assumption of memory advantage for exceptions. In Experiment 1, we tested the claim of memory advantage for exceptions in situation of learning categories that have exceptions that violate previous expectation since they look more like the members of the other category and they also violate the category rule. However, in contrast to the exceptions used in the previous studies that respect contrasting category rule, they have a new rule on the deterministic dimension, which is on its own sufficient for successful categorization. In Experiment 2, the structure of the regular category members remained the same, but the nature of the exceptions was changed. In Experiment 2, exceptions were items that had all features new. Since exceptions in our study are individuals, for this latter kind of exceptions, different kinds of rules could be formed, since each feature is fully predictive.

Although the exceptions used here are very different from the ones used in the previous studies, they retain all the characteristics that are assumed to contribute to their special status in memory. They are rare, they may be studied for unlimited amount of time, and, most importantly, they violate the expectations based on the knowledge of regular items, both in terms of rule and appearance. On the other hand, they could be categorized equally successfully by employing different learning mechanisms and forming different representations, which makes them advantageous in comparison to the types of exceptions that could be learned by memorizing only.

Additionally, we examined developmental differences in learning and representing exceptions. Two age groups participated in the experiments: four-year-olds and adults. As previously described, a developmental study is particularly interesting since it will allow test of differences in the memory status of exceptions under regimes of distributed end selective attention category learning.

Experiment 1

Method

Participants

Participants were 27 four-year-old children (Mage = 54.6 months, range 48.5 – 59.9 months, 14 girls) and 36 adults.

Data of one additional child and one adult participant were excluded due to the failure to discriminate between old (High-Match) items and items that had 5 of 6 features completely new (All-new-P) (A' not different from chance level of 0.5, one sample t-test *ps* > .05).

All four-year-olds that took part in the experiments reported in this paper were recruited from preschools located in middle-class suburbs of Columbus. In order to take a part in the study they had to be between 48 and 60 months old. They were tested during their regular school hours in a quiet room in their preschool.

All adults that participated in the experiments reported here were The Ohio State University undergraduate students. They were tested in a quiet room in the laboratory located on campus and they received course credits for their participation.

Stimuli

Stimuli were artificial dinosaur-like creatures created using Spore Creature Creator and Gimp (Figure 1). These creatures were accompanied by two novel category labels: Lulu and Momo.

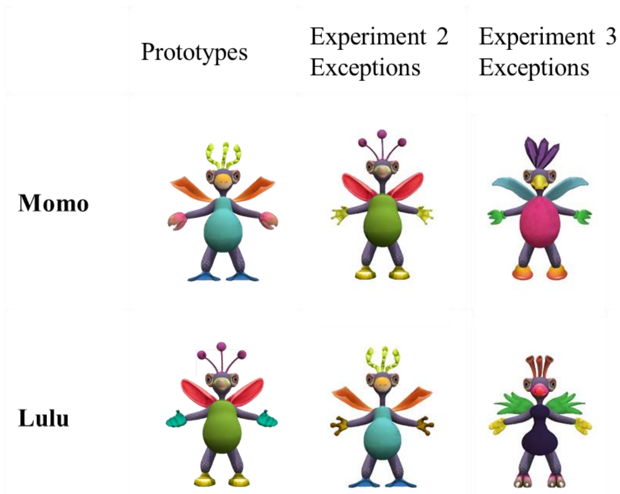

Figure 1. Examples of stimuli used in the study where hands are the rule feature.

The category structure

The categories of Lulus and Momos were dense 7-dimensional categories with 1 non-diagnostic dimension, 5 probabilistic dimensions and 1 deterministic dimension (Table 1). Non-diagnostic dimension varied independently and gave no information about the category membership. Probabilistic dimensions varied between categories and within-category, with significantly higher between-category in comparison to within-category variance. Hence, probabilistic dimensions were predictive when taken together, since they reflected the overall similarity between category items. Deterministic dimension was fully predictive.

The neck length (short/long) was always the non-diagnostic dimension. The other 6 dimensions were: antennas, mouth, belly, wings, hands and feet. All dimensions were binary. The choice of deterministic feature (belly or hands) was balanced across the participants. Table 1 presents the structure of training and test items.

During the training, only High-Match and Exception items were presented. High-Match items always respected the category rule and had most of the probabilistic features of their own category (4 of 5). Exceptions were designed so they look more like the other category members (they had probabilistic features of the other category) but they also had a new rule feature.

In the test session, in addition to items presented during the training (High-Match and Exceptions), there were additional 4 types of items. Those new items were based on High-Match and Exception items, but either had one probabilistic feature new (One-new-P, E-One-new-P), or all probabilistic features new (All-new-P, E-All-new-P).

Design and procedure

For adults, all instructions and questions were written on the screen and they responded by pressing designated keys on a computer keyboard. For four-year-olds, all instructions and questions were read by a trained experimenter who collected their verbal responses using a computer keyboard.

Table 1: The abstract category structures used in Experiment 1 and Experiment 2.

	Momo						Lulu					
Experiment 1												
	Probabilistic					Rule	Probabilistic					Rule
High Match	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**
New-D	1	0	0	0	0	N	0	1	1	1	1	N
One-new-P	0	N	0	0	0	0	1	N	1	1	1	1
All-new-P	N	N	N	N	N	0	N	N	N	N	N	1
Exception	**1**	**1**	**1**	**1**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**3**
E-One-new-P	1	N	1	1	1	2	0	N	0	0	0	3
E-All-new-P	N	N	N	N	N	2	N	N	N	N	N	3
Experiment 2												
	Probabilistic					Rule	Probabilistic					Rule
High Match	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**
New-D	1	0	0	0	0	N	0	1	1	1	1	N
One-new-P	0	N	0	0	0	0	1	N	1	1	1	1
All-new-P	N	N	N	N	N	0	N	N	N	N	N	1
Exception	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**
E-New-D	4	4	4	4	4	N	5	5	5	5	5	N
E-One-new-P	4	N	4	4	4	4	5	N	5	5	5	5
E-All-new-P	N	N	N	N	N	4	N	N	N	N	N	5

Instructions

After the cover story about the two dinosaur families, Momos and Lulus, was read, participants were presented with the prototypes of Momos and Lulus. The prototypes were presented together, on the same screen. Participants were told that that is how Momos and Lulus usually look like and each of the six features of the two creatures was introduced, using the sentence frame: "Momos/Lulus usually have antennas like these" and pointing to the named feature (Figure 2).

Training

During the training participants were presented with the exemplars of Lulus and Momos and they were asked to classify them. Items were presented individually in the center of a white background screen, accompanied by the question "Is this is a Momo or a Lulu?" Two buttons, labeled Momo and Lulu, were presented on the same screen. Participants responded by pressing one of the buttons if adults, or giving verbal answers if children. After they made a response, corrective feedback was provided. Feedback had two elements. First, the button of the correct response was presented (that is, the correct answer button stayed on the screen) and second, feedback sentence was presented. If participant gave the correct answer, she received message "That's right! That's Momo (Lulu)!" If participant made a wrong choice, message "Oops! That's Momo (Lulu)!" was presented.

During the training session, 70 items were presented: 60 High Match items and 10 Exceptions. In the first block only High Match items were presented (20), while in the second and the third block participants saw both High Match (20) and Exception (4) items in random order. At the end of the third block, we presented additional 2 Exception items. The logic behind the dynamics described was that in order for Exceptions to be seen as Exceptions they should be presented after a representation of High-Match items was formed, and they needed to be less frequent. Order of presentation was randomized for each participant.

Memory test

Memory test was introduced immediately after the training session. Items were presented individually, followed by the question „Did you see exactly the same creature in the first part of the game?" and two buttons labeled „old" and „new". After participant gave a response, the next trial was presented. There was no feedback.

Memory test was given in one block. It had 64 trials in total, 8 trials of each item type, presented in random order.

Results

Training performance

For both age groups, average accuracy in categorizing High-Match items was above the chance (one-sample t-tests against chance yield *t*s > 2.70, both *p*s < .05, two-tailed).

Both groups of participants misclassified Exceptions. The average proportion of accurately classified items was .41 for four-year-olds and .33 for adults, based on performance on all 10 items presented during the training session (both bellow the chance, *t*s > 2.38, *p*s < .05). Since Exceptions had probabilistic features of the other category High-Match items, participants based their responses on the overall similarity of exceptions to High-Match items.

Recognition memory

In order to estimate participants' recognition memory, we calculated A' scores (Snodgrass, Levy-Berger, & Haydon, 1985). A' is a non-parametric analogue of the d' statistic (Brophy, 1986) and it is a measure of discriminability. No discrimination (chance performance) is indicated by value of 0.5. With better discrimination the A' score increases.

Both age groups demonstrated high recognition accuracy (old – All-new-P). Average memory sensitivity scores were well above chance (both *ps* < .001).

To examine the hypothesized differences in memory for regular items and exceptions, A-prime scores were subjected to a two-way (Age by Type) ANOVA.

For the overall memory (old – All-new-P) the analysis indicated that there was no significant main effect of item type ($p > .05$), whereas the main effect of age was significant, F (1, 120) = 8.87, $p < .01$, $\eta = .07$ with 4-year-olds' performance being significantly lower than adults' performance (Figure 2).

The pattern was the same for the memory for probabilistic features. Again, adults have shown better memory than 4-year-olds (F (1, 120) = 8.61, $p < .01$, $\eta = .07$) and there was no difference in memory for regular items and exceptions.

Note here that the lack of difference in memory for regular and exceptional items may be due to poor learning. This problem is resolved in Experiment 2.

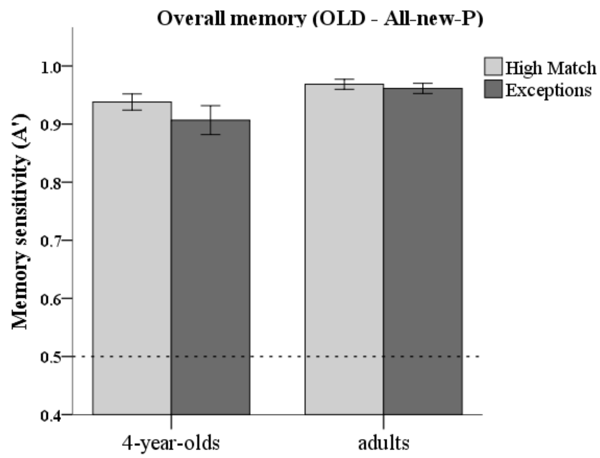

Figure 2. Memory sensitivity scores (A-prime) for overall memory (OLD – All-new-P) across age groups and two item types in Experiment 1. The dashed line represents the point of no sensitivity. Error bars represent the standard errors of the mean.

Experiment 2

Method

Participants

Thirty-three four-year-olds (Mage = 52.6 months, range 44.0 – 53.6 months, 12 girls) and 39 adults took part in Experiment 3. Three additional 4-year-olds and one adult were excluded based on the same criteria used in Experiment 1(A' not different from chance level of 0.5, one sample t-test, all *ps* >.05). Participants were recruitment from the same participants' pool as in Experiment 1.

Stimuli

The structure of the High-Match items and accompanying test items was the same as in the Experiment 1. The same stimuli set was used. Exceptions were different. They had all features new. Exceptions were individuals, thus there was one exception of Momo and one of Lulu category.

In addition to the stimuli types used in the Experiment 1, there were 2 additional item types: New-D and New-D Exceptions (See Table 1).

Design and procedure

Design and procedure of Experiment 2 respected the one described for Experiment 1 in every respect. Memory test had

88 trials. The experiment took approximately 15 - 20 minutes for adults and 25 - 30 minutes for children.

Results

Training performance

Performance on High-Match items was above chance for both age groups (*ts* > 4.78, both *ps* < .001, two-tailed). Both children and adults learned to categorize exceptions (*ts* (36, 23) = 3.57, 6.64, *ps* < .001).

Recognition memory

Overall memory sensitivity was high for both age groups and well above chance (both *ps* < .001) (Figure 3). Differences in overall memory (old – All-new-P) were tested in a 2 (Age: 4-year-olds, adults) x 2 (Type: regular, exception) ANOVA. Participants had better memory for regular items (A' scores), regardless of their age (F (1, 140) = 4.88, $p < .05$, $\eta = .03$).

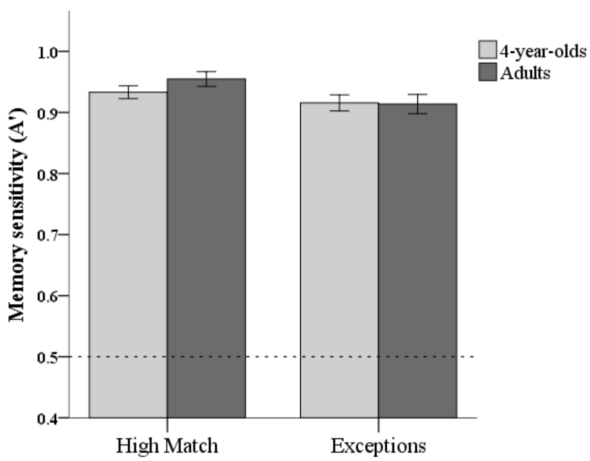

Figure 3. Memory sensitivity scores (A-prime) for overall memory (OLD – All-new-P) across age groups and two item types in Experiment 2. The dashed line represents the point of no sensitivity. Error bars represent the standard errors of the mean.

In order to test for differences in memory for (P and D) features, 2 (Age: 4-year-olds, adults) x 2 (Type: regular, exception) x 2 (Feature: P, D) ANOVA was conducted on A' scores. The analysis revealed significant main effects of age (F (1, 280) = 5.13, $p < .05$, $\eta = .02$) and type (F (1, 280) = 13.26, $p < .001$, $\eta = .05$), and a significant age by feature interaction (F (1, 120) = 6.05, $p < .05$, $\eta = .02$) on A' scores. As expected based on the previous studies (Deng & Sloutsky, 2016), adults, but not 4-year-olds, have shown differential memory - specifically better memory for rule than probabilistic feature. Both age groups had better memory for features of High-Match items, than those of exceptions (Figure 4).

Discussion

Results presented in this paper challenge assumptions of the models of classification learning like RULEX and SUSTAIN. In two experiments reported here we have shown that both children and adults have better memory for features of regular items than features of exception. These findings have at least two important implications. First, they show that regular category members are not processed minimally, as it is suggested by models which assume high level of optimization of attention. Secondly, they also show that exceptional items are not represented fully, that is, they are not necessarily memorized. Not only that RULEX model cannot account for these findings, but it predicts completely the opposite pattern. Although SUSTAIN would fit the data better (especially good memory for regular items), the finding of better memory for exceptions runs counter to its assumptions.

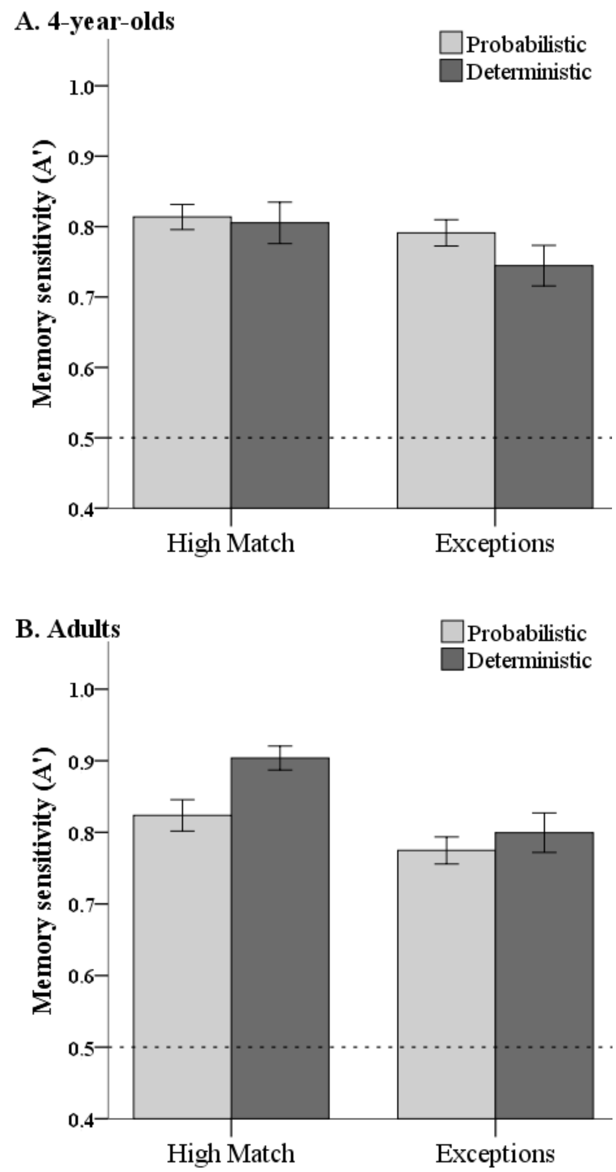

Figure 4. Memory sensitivity scores (A-prime) for probabilistic and deterministic features of two item types in Experiment 2 (Panel A: four-year-olds; Panel B: adults). The

dashed line represents the point of no sensitivity. Error bars represent the standard errors of the mean.

The representation of an exception depends on its nature. When exceptions violate categories defined by rules by respecting contrasting category rule and can be learned only if there is binding of features, there is better memory for exceptions than regular items, as shown in the previous studies (e.g. Palmeri & Nosofsky, 1995, Sakamoto and Love, 2004). However, when the nature of exceptions, and the nature of a category they belong to, allows for more flexible approach, participants tend to optimize. In the case of the exceptions used in this study, they could be equally successfully categorized based on different representations, some of which could simply contain memory for one of the item's features. However, despite their easy-to-learn structure, if special status of exceptions is to be attributed to the fact they violate previous knowledge expectations, they are schema-inconsistent and rare, exceptions in our study would also be processed with more attention, more deeply and they would have stronger memory trace. However, this was not the case.

Contrary to the predictions based on schema literature, that participants are more prone to notice missing features or new features in schema-inconsistent items than schema-consistent items (Friedman, 1979; Goodman, 1980), our participants were more sensitive when we changed regular items' features.

In addition to the difference in memory for regular category members and exceptions, developmental differences in memory were also found. While adults had better memory for rule, than for probabilistic features, 4-year-olds didn't show differential memory. This pattern is in accordance with previous studies (Deng and Sloutsky, 2016). However, contrary to our predictions, there were no developmental differences in memory status of exceptions. Both age groups had better memory for regular category members, despite differences in attention allocation (selective vs. distributed).

Taken together, findings of this study suggest new directions for models of category learning and memory, by providing new evidence on attention and memory optimization during category learning.

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