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More like a bee, less like a spider, and not like a tomato: Ecologically-valid enrichment experiences promote changes in how young children differentiate biological categories

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Abstract

Knowledge about categories supports learning and generalization, and this knowledge is particularly important early in development. Although most theories of category knowledge posit a role for experience in acquiring this knowledge, the current evidence for the presumed role of experience in category knowledge acquisition remains limited to correlational evidence, indirect measures of category knowledge, and computational studies. Here we provide direct evidence that repeated experience with a biological domain in an ecologically-valid setting changed children's category representations, with increased differentiation of items within that domain and relative to a second domain. The implications of these results for understanding the role of experience in category acquisition, and the contribution of enrichment experiences to school readiness are discussed.

Keywords: categories; differentiation; learning; development

Introduction

Learning and using categories fundamentally changes human cognition and learning. For example, adults perceive items that belong to the same category as being more similar to one another, use relevant features to discriminate among categories, and take advantage of category knowledge to make inferences about new items (Smith & Medin, 1981). Learning and using categories also plays a fundamental role early in life, as category knowledge allows children to efficiently attend to information in the environment (Vales & Smith, 2017), encode and retrieve information (Bjorklund, & Jacobs, 1985), and make inferences (Fisher, Godwin, & Matlen, 2015; Gelman & Markman, 1986). While much is known about how category knowledge influences cognition and learning, there is still much we do not know about how this knowledge is acquired early in development and how experience shapes knowledge of categories. Here we provide initial evidence that ecologically-valid enrichment experiences in a domain promote changes in how children represent categories both within that domain and relative to a distinct domain by (1) increasing the similarity among items of a category within a domain while decreasing the similarly between items of different categories within a domain, and (2) decreasing the similarly between items of distinct domains.

The acquisition of categories and the ability to use category knowledge in the service of learning – by treating different items as equivalent for some purpose – allows humans to go beyond individual items and generalize what is known about items of a category to other items of the same category (Badger & Shapiro, 2012; Yamauchi & Markman, 2000). For example, if one knows that birds can fly, then one can generalize that a newly-encountered feathered creature likely can also fly. Using category knowledge does not always guarantee correct inferences; nevertheless, category-based generalization is a key feature of mature cognition. The ability to make category-based generalizations is likely to be especially important early in development when much of the information that children encounter is novel and thus needs to be integrated into existing knowledge. Indeed, prior research has shown that the ability to generalize a new property from one item to another item of the same biological category (e.g., from *lamb* to *sheep*) is related to how similar children perceive those two items to be (Fisher, Godwin, & Matlen, 2015). Similarly, children who are "dinosaur experts" can use relevant prior knowledge in this domain to describe specific items (e.g., "[this dinosaur is a] plant-eater, 'cause it has little teeth that aren't sharp"), whereas control children are more likely to describe superficial features (e.g., "[this dinosaur] has sharp fingers, sharp toes, a big tail"; Gobbo & Chi, 1986). These individual differences in category knowledge are likely to also influence performance in academic settings; for example, background knowledge in a domain (e.g., how much a child knows about spiders) predicts how well a child learns new information from text in that domain (Pearson, Hansen, & Gordon, 1979). Together, this evidence illustrates how category knowledge supports learning and generalization in childhood.

Given the importance of category knowledge to learning and generalization, and that individual differences in category knowledge exist early in development, an important question is how young children acquire this knowledge. The existing literature makes a compelling case for changes in category knowledge as a result of experience. For example, when shown pictures of cats and dogs, children who own pets spend more time visually inspecting the relevant features of those categories relative to children who do not own pets (Kovack-Lesh, McMurray, & Oakes, 2014). Similarly, relative to urban children, children of rural settings and children who spend more time in nature are more accurate at making category-consistent generalization in the animal domain (Coley, 2012). It is possibly that these

children's experiences with house pets and animals have changed their stored representations of these categories, influencing how children visually inspect objects and how they use category knowledge to make generalizations. Consistent with this possibility, a training study with infants has shown that exposing infants to novel object categories changes how infants visually inspect those categories (Bornstein & Mash, 2010). Finally, computational studies show that categories meaningfully organized within- and across-domains can, in principle, be learned from accumulating information about individual items in those categories (Hills et al, 2009; Kemp & Tenenbaum, 2008; McClelland, & Rogers, 2003; see also Shapiro et al., 2013 for related evidence). For example, Hills et al. (2009) have shown that the features associated with the nouns known by most children before age 3 provide sufficient information to aggregate those nouns into groups that resemble adult-like domains (e.g., food, animals, vehicles); importantly, as more features become available, the more differentiated those domains become. This increase in differentiation likely reflects both increased similarity within items of a domain and decreased similarity between domains, akin to what is seen in categorization training studies with adult participants (Goldstone, Lippa, & Shiffrin, 2001).

Although the evidence discussed above is consistent with experience-driven changes in category knowledge, three open questions remain. First, the evidence relying on pre-existing individual differences (e.g., pet ownership, children from rural vs. urban setting) offers only a correlational link between experience and category representations. Second, the experimental evidence available remains limited to attentional measures, and thus offers only indirect evidence for changes in category representations and does not specify how those category representations change as a result of experience. Third, the predictions from computational studies on category differentiation as a result of experience remain largely untested in young children (but see Unger et al., 2016; Unger & Fisher, 2017). To fill these gaps, we examined whether participating in informal enrichment experiences at a botanical garden promoted changes in category representations in preschool-aged children. We chose to investigate this question in the context of an informal learning activity because prior literature has documented that these experiences (e.g., visiting a science museum or a botanical garden) expose children to science-relevant categories (Crowley & Jacobs, 2002). Young children are less likely to have differentiated representations of these categories (e.g., Hatano et al., 1993), and thus an informal learning context such as the botanical garden offers an opportunity to examine experience-driven changes in children's category differentiation.

The present study

In the present study, we tested the hypothesis that ecologically-valid, enrichment opportunities change how children represent categories, specifically increasing category differentiation within and across domains. To test this hypothesis, we recruited children who were enrolled in one of two informal learning programs at a botanical garden. The two programs had equivalent structures and activities, but focused on two different biological domains (*bugs* and *plants*). The programs took place daily for 2.5h over the course of a week. The examples of the activities from both programs listed in Table 1 highlight the informal nature of these programs, as does the fact that the activities involved interaction with social partners in the context of meaningful activities that made use of hands-on, concrete tools, and that presented no consequence or direct assessment of children's learning (Callanan, et al., 2011; Rogoff, et al., 2016). Importantly, these activities exposed children to many items within a domain, conceivably increasing the availability of features that can be used to differentiate items within and across domains.

Table 1: Example of activities from the two programs.

Bugs program	*Plants program*
craft: exoskeleton t-shirts	craft: decorate t-shirts with plant stamps
hunt for (plastic) bugs	hunt for pumpkin seeds
butterfly lifecycle play	seed lifecycle play

To examine whether these informal learning activities promoted changes in how children represented biological categories, children completed a similarity-judgment task before starting the first day of the program and after completing the last day of the program. This task, which has been used in past work to elicit similarity judgments from both adults and children (Fisher, et al., 2015; Goldstone, 1995), allowed us to collect pairwise similarity judgments of multiple items both within and across two domains in a single trial. Children were asked to arrange items on a game board with a visible grid such that items that were the same kind of thing were placed close together; these instructions have been shown to yield judgments of both within- and across-domain similarity in children (Unger at al., 2016). We then used the physical distance between items on the board as a judgment of similarity for each pair of items: items placed at shorter distances were judged as more similar. If these informal learning activities, by virtue of exposing children to many items of a domain, promote differentiation both within- and across-domains, then we would expect children's arrangements of items on the board to show differentiation of categories within a domain from before to after completing the program activities, while also showing differentiation across domains. For example, a child who participated in the *plants* program would (1) judge items that belong to the biological category of 'fruits' as more similar (i.e., place them closer together) from pre- to post-test, (2) better discriminate 'fruits' from other non-fruit plants (i.e., place them further apart) from pre- to post-test, and (3) judge items from the domain of 'plants' as more dissimilar to another domain (i.e., 'bugs') by placing them further apart from pre- to post-test. We also probed the

specificity of these experience-driven changes by including items both from the domain of the program a given child completed (e.g., *plants*) and the domain of the other camp (*bugs* in this example), and examining whether changes (1) and (2) predicted above also occurred for the other domain (*bugs* in this example); if changes in category knowledge are happening as a result of experiencing items of a domain, then we would expect within-domain differentiation to occur only for the domain a child experienced.

Methods

Participants

Twelve children (5 girls) between 4 and 5 years of age (M=4.5, SD=0.5) were recruited from a group of children enrolled in one of two informal learning programs at the Phipps Conservatory and Botanical Gardens in Pittsburgh, PA in the northeastern United States. Three additional children were recruited but not included in the analyses due to being unable to complete the post-test session (N=2) and loss of data (N=1). Caregiver consent was obtained for all participants, and children received a gift for participating.

Stimuli and Design

We created two sets of stimuli, one for each program domain (see Fig. 1). For each domain, there were two types of items: same-category items (that belonged to a biological category of that domain) and different-category items (that did not belong to the same category as the same-category items, but to another category in that domain). The same-category items included both items that were experienced in the program (i.e., that were part of the activities) and items that were not experienced in the program. The two biological categories tested were *insects* (defined by having three body parts and antennae) and *fruits* (defined by containing seeds). The different-category items were, respectively, bugs that are not insects and plants that are not fruits (i.e., do not contain seeds); the different-category items were not part of the camp activities. The items were selected based on the objectives and the activities of the programs; the educators leading the program activities were blind to the specific hypotheses of this study. A black and white line drawing representing each item was printed on 5x5cm cards with a white background, for a total of 18 cards. The cards were arranged by the children on a game board with a visible 10x10 grid of 6.3cm squares.

Children were tested before starting the program activities on the first day of their program (pre-test) and after completing the program activities on the last day (post-test). Because our predictions concern both within- and across-domain differentiation, children were asked to arrange all 18 cards in one trial.

Procedure

Both at pre- and post-test, children sat with an experimenter at a table in a quiet area of the botanical garden; caregivers were instructed to not influence the child's arrangement of the cards. Children were told that the goal of the game was to organize cards with animals and plants on the game board, such that cards depicting items that are the same kind of thing are placed close together and cards depicting items that are not the same kind of thing are placed far apart; while giving these task instructions, the experimenter brought their hands close together and moved them apart above the board. The experimenter then laid the cards on the table, one at a time, while labeling them (e.g., "Here is a *butterfly*"); the cards were shuffled before each participant. Once all cards were labeled by the experimenter, the child was reminded of the instructions and asked to arrange the cards on the board; once half of the cards had been placed, the experimenter reminded the child of the instructions. Children were also told that they could re-arrange the cards at any time and could take as long as they wished to arrange all cards. Once all cards were arranged, children were asked if they were happy with how their cards looked and if they wanted to change anything; the experimenter also clarified any cards that were not clearly placed (e.g., in between 2 grid cells; "Can you show me where this one goes?"). Once the child confirmed their final arrangement, the experimenter thanked them for their help, and took a photo of the board for later coding.

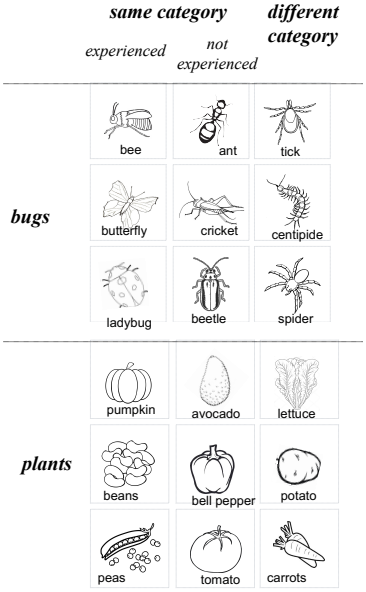


Figure 1: Stimuli used in the experiment; the item names were not displayed on the test cards.

Results

Data Coding and Scoring

The photo of each subject's pre- and post-test arrangement was coded by coders blind to the specific hypotheses of the study. Coders used the 10x10 grid as a coordinate plane and coded the coordinates of each card on the board; a second coder verified the accuracy of all coordinates for all

children. From the coordinates, we calculated distance scores for all pairs of items of interest by computing the Euclidian distance between the points specified by the coordinates of each card of a pair.

Data Analyses

Our main hypothesis concerns the role of experience with a biological domain in increasing differentiation both within that domain and relative to another domain. Specifically, if experience with a biological domain influences how children represent categories in that domain and relative to other domains, then we would expect children to show increased within-domain differentiation (both by judging same-category items as more similar from pre- to post-test and by judging different-category items as more dissimilar from pre- to post-test) while also showing across-domain differentiation (by judging items from different domains as being more dissimilar from pre- to post-test). To examine these hypotheses, we calculated distance scores for the pairs of items that reflected the relevant contrasts for each prediction. For example, to examine whether children judge in-domain different-category items as more dissimilar from pre- to post-test, we calculated distance scores for all pairs within a domain that belong to different categories (i.e., all pairs that include a bug that is an insect, and a bug that is not an insect; or a plant that is a fruit and a plant that is not a fruit). Smaller distance scores, that is, items that were placed closer together, indicate higher similarity.

Within-domain differentiation Figure 2 depicts the mean distances scores for pairs of items of the domain a child experienced vs. did not experience (top vs. bottom panels), and for same-category vs. different-category items within a domain (left vs. right panels). The figure suggests that, for the *domain a child experienced*, same-category items are judged to be more similar from pre- to post-test and different-categories items are judged to be more dissimilar from pre- to post-test. Importantly, no such change is apparent for the corresponding pairs of items for the *domain a child did not experience*. To examine whether children's representations of biological categories from the domain of the program they experienced changed as a result of participating in this enrichment experience, we built a linear model in the R environment using the lme4 package to analyze the effect of phase (pre- vs. post-test), category type (same-category vs. different-category), and domain (domain experienced vs. not experienced) on the distances between items. We included subject as a random factor, i.e., varying around a group mean; Wald F tests and respective p-values were calculated using Kenward-Roger's approximation. The model showed that the interaction between phase and category type was a significant predictor of distance in the model, $F(1,1445)=5.1$, $p=0.02$ as was the three-way interaction between phase, category type, and domain, $F(1,1445)=4.9$, $p=0.03$; all other interactions and predictors were not significant predictors of distance (all $F<1$, all $p>0.34$). Thus, whether children's judgments of similarity changed from pre- to post-test depends on both the relation between the items in a pair (same- vs. different-category) and on whether the pair reflected a relation from the domain they experienced in their program or from the other domain. To follow up on this interaction, we conducted planned contrasts comparing pre- and post-test distances within each type of category and domain. For the domains children experienced, these contrasts showed a marginal effect for same category items ($F(1,1451)=2.8$, $p=0.09$) such that children placed same-category items from the domain they experienced closer together from pre- to post-test; and a significant effect for different-category items ($F(1,1451)=8.6$, $p=0.003$), such that children placed different-category items from the domain they experienced in camp further apart from pre- to post-test. Importantly, these same children did not change the relative distance at which they placed same-category ($F(1,1451)=0.04$, $p=0.84$) or different-category ($F(1,1451)=0.07$, $p=0.79$) items from the domain they did not experience.

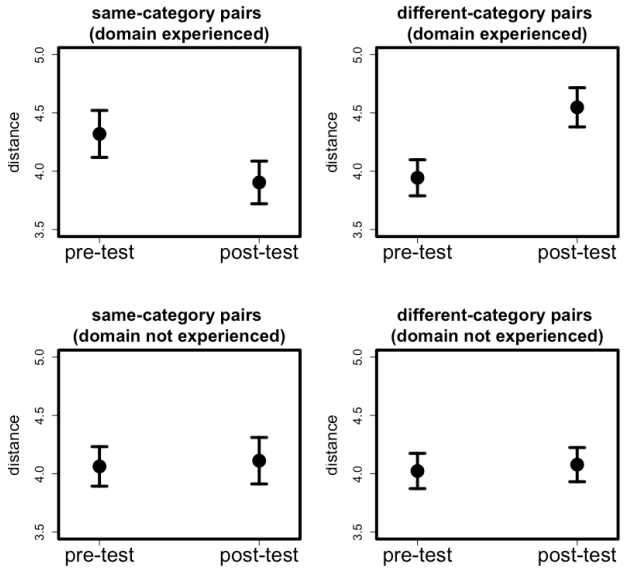


Figure 2: Mean difference scores for pairs of items from the domain a child experienced vs did not experience (top vs. bottom panels), and for same-category vs. different-category items within a domain (left vs. right panels).

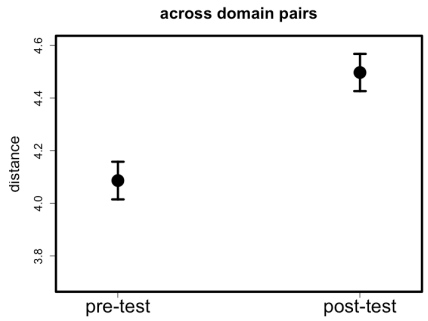


Figure 3: Mean difference scores for pairs of items that belong to different domains (*bugs* vs. *plants*).

Across-domain differentiation Figure 3 depicts the mean distance for items that belong to different domains (that is, *bugs* vs. *plants*) before (pre-test) and after completing the program activities (post-test). As can be seen, after completing the camp activities, children placed items that belonged to different domains farther apart on the board, $F(1,3659)=15.1$, $p= 0.0001$, thus judging these items to be more dissimilar after experience with one of those domains.

Discussion

The results of this study provide two main conclusions. First, children's representations of biological categories changed as a result of experiencing multiple items from a domain; same-category items became more similar and different-category items became less similar. Importantly, this change was experience-specific, that is, there was no change in children's similarity judgments for equivalent pairs of a domain they did not experience. Second, the current results show that experience with items from a domain also changed how children represented that domain relative to a second domain; the two biological domains (i.e., bugs and plants) became more dissimilar as a result of this experience. These results have important implications for understanding the role of experience in category acquisition, and for conceptualizing the contribution of enrichment experiences to school readiness.

Despite theoretical discussions on how children acquire category knowledge, most contemporary theories sustain that experience plays a role in acquiring such knowledge. Although there is evidence supporting the role of experience in acquiring category knowledge, most of the existing evidence is correlational and does not specify how category representations change as a result of experience. Here, we provide direct evidence that experience in a domain specifically changed how children differentiated categories within that domain. These results are consistent with the idea that, as children encounter different items within a domain, they accrue knowledge about the relevant features for category membership, such that items within a category (by virtue of sharing more features) become more similar to one another and more dissimilar to other categories. Prior computational work has shown that such a mechanism – tracking the relevant features, and the correlation among features – can in principle support the aggregation of items into categories and domains (Hills et al, 2009; Kemp & Tenenbaum, 2008; McClelland, & Rogers).

Importantly, children not only differentiated among same- and different-category items *within* a domain, but also *across* domains. That is, extensive experience with items of one domain changed how items in that domain were perceived *relative to items of a distinct domain*. We do not mean to imply that in the period between pre- and post-test, children had no exposure to items of the other domain; likely, children encountered bugs and plants in their daily lives in addition to their experiences at the botanical garden. Yet, it is noteworthy that a relatively brief experience with one domain produced measurable differences in how children represented items of that domain relative to a second domain. Changes at the global level as a result of experience with items at the local level are also captured by models that track regularities in the input (e.g., Plaut, et al., 1996), and thus it is plausible that experiencing and learning the features of *bugs* makes them more dissimilar relative to *plants*, and vice-versa. Future work can more directly examine these possibilities by manipulating the feature space of categories in children's experience.

One point of contention in current theories of category learning concerns the role of perceptual features (perceived properties of an item, e.g., "it has seeds") versus conceptual features (properties of an item that concern its relation to other items or events, e.g., "it is alive") in children's early category learning (Gelman & Markman, 1986; Sloutsky & Fisher, 2004), with both views finding evidence that young children use perceptual and conceptual features when grouping items and when making category-based inferences. In our study, children likely experienced both kinds of features; that is, although the items with which we tested our participants were organized based on perceptual features (i.e., having a three-part body and antennae; containing seeds), the program activities likely exposed children to both kinds of features. For example, children in the plants program were exposed to multiple items with seeds inside, and also had the opportunity to experience the lifecycle of a seed and thus understand that plants are alive. Prior computational work suggests that both kinds of features play a role in acquiring categories organized by domains (Hills et al., 2009), with perceptual features seemingly supporting domain inclusion and conceptual features conceivably supporting domain discrimination. Further, the acquisition of what one might call "conceptual" features might result from learning overlapping "perceptual" features (Smith, Colunga, & Yoshida, 2010). Future work can more directly test these predictions by manipulating the features that children experience, and examining the resulting category representations and category-based inferences.

The current work is also relevant to the broader literature on school readiness and academic achievement. After participating in a relatively brief, informal learning experience, children showed evidence of having acquired more fine-grained distinctions within the biological domain they experienced, and relative to another biological domain. Because learning to classify animals and plants based on their biological groups is often included in educational standards at the elementary school level, enrichment activities such as this one might support the acquisition of what prior research has identified as "background knowledge", a key component for success in academic-like activities (e.g., Pearson, Hansen, & Gordon, 1979). One of the key features of development is that it builds itself in time; past learning both opens and limits opportunities for new learning. Lack of access to enrichment opportunities where children can acquire initial distinctions relevant for academic contexts may limit children's future school performance. On the other hand, understanding how these

experiences change children's representations of academic-relevant categories can open up new avenues to develop targeted interventions aimed at improving school readiness.

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