Multi-Level Induction of Categories:
Venomous Snakes Hijack the Learning of Lower Levels

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Abstract

The induction of categories and concepts from examples—which plays an important role in how we come to organize and understand the world—can happen at multiple levels, but how does competing values of these different levels affect their learning? Using perceptually rich images of snakes that could be categorized by their specific genus or a broader category, and that varied in value (whether the snake was venomous vs. whether it was tropical), we asked participants to attend to one level but tested induction at both levels. We found an interaction between study instruction and intrinsic value: Participants in the low-value condition were better able to induce the instructed level, whereas participants in the high-value condition, were significantly better at learning the broad category (i.e., venomness), regardless of instruction. Our results suggest that intrinsically valuable features can affect learning by disrupting the intentional learning of other, task-relevant information, but enhancing the incidental learning of these same features.

Keywords: learning, implicit memory, induction, category-learning, value

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Research on category learning has focused on the nature of induction, such as whether it is explicit or implicit (e.g., Maddox & Ashby, 2004), prototype-based or exemplar-based (e.g., Posner & Keele, 1968; Medin & Schaffer, 1978) and on the presentation schedules that optimize inductive learning (e.g., Kornell & Bjork, 2008; Kang & Pashler, 2012; Zulkiply & Burt, 2013), but there has been less concern with the factors that affect the induction of multiple category levels. Virtually every item can fall into a number of broader or more specific categories, and some levels may be more important to know than others. An art course, for instance, might prioritize learning styles of individual artists, versus learning about the different eras of art. Personal agendas and preferences may also play a role: An art major might place greater value on learning individual artist's styles than would a student taking the course to fulfill a distribution requirement.

The value accorded learning at a given level may also be guided by universal principles, such as survival. Knowing whether a snake is venomous, for example, may have greater importance, survival value, and/or self-relevancy than knowing its specific genera. Though the effects of value-driven encoding have been studied extensively in memory (whether value is defined as experimenter-assigned points, Castel, Benjamin, Craik, & Watkins, 2002; survival-relevancy, Nairne & Pandeirada, 2008; or self-reference, Symons & Johnson, 1997), value-effects have not been examined within the domain of category learning. Certain categorizations are, however, often considered to be more important to learn (e.g., identifying malignant vs. benign tumors) than are others (e.g., identifying igneous vs. sedimentary rocks). Investigating the inductive learning of intrinsically valuable categorizations is, therefore, not only interesting, but highly relevant to the classification and organizational processes used to learn and form categories in everyday life.

Furthermore, research has typically focused on learning only one level of categorization, but has neglected to explore whether attending to a more specific level can lead to incidental learning of a higher-order category, and vice versa. Using snakes as stimuli, we examined how extrinsic (e.g., having to learn for a class or a test) and intrinsic values (e.g., personal preference or survival value) guide the simultaneous learning of multiple category levels.

An instruction to prioritize learning one level of categorization—for example, to focus either on genus or a broader category (e.g., venomness or tropical-ness) between snakes—might be considered an extrinsic, experimenter-defined value. Studies using a value-directed remembering paradigm (e.g., Castel, Benjamin, Craik, & Watkins, 2002; Castel, 2008) have shown that people are able to direct their attention selectively toward, and recall, more objectively-defined valuable items, but perceived value can be, and often is, determined intrinsically (see Castel, 2008). A person might be more likely to remember a grandchild's birthday, for example, not because they were instructed to, but because of how important that person is to them, and—of more relevance to the present study—someone may place high value on learning to distinguish venomous snakes from other snakes, given the intrinsic value of such survival-relevant information (Nairne & Pandeirada, 2008). In fact, survival processing has been demonstrated to enhance recall substantially (e.g., Kang, McDermott, & Cohen, 2008; Weinstein, Bugg, & Roediger, 2008; Nairne & Pandeirada, 2010; Soderstrom & McCabe, 2011).

While Nairne and Pandeirada have theorized that humans have evolved to place greater intrinsic value on survival-relevant information, other researchers have offered different explanations for why "survival processing" leads to superior recall. Butler, Kang, and Roediger (2009), for instance, argue that the survival processing benefit is eliminated when relevance of items to different processing conditions is equated. Others (e.g., Klein, Robertson, & Delton, 2011) have suggested that planning strategies drive the survival processing effect.

In the survival processing literature, intrinsic value of the items has been manipulated via an extrinsic processing mindset, such as telling participants to imagine that are on grasslands or in a city. It seems plausible, though, that certain to-be-learned items can elicit a “survival” mindset. Snakes, for example, pose a deadly threat to humans, and research on fear has suggested that we have evolved to be especially alert to snakes (Ohman & Mineka, 2001). Indeed, snakes possess an intrinsic quality—the presence or lack of venom—that has great relevance to survival. In our present study, using snakes as exemplars, we manipulated the extent to which our stimuli elicited survival processing by labeling the snakes as venomous and non-venomous, or tropical and non-tropical.

We examined the effect of explicit study instructions and intrinsic value on learning broad and specific (i.e., genus) categories of snakes. Of interest are two questions: First, can people, while focusing on one level of categorization (broad or specific), also learn, incidentally, the other level of categorization? Second, how is this multi-level category learning affected by intrinsic value, particularly when related to survival? In our materials, we presented participants with images of snakes. These snakes can be categorized into six snake genera (the specific category in the present study). These six genera, however, also fall into one of two broader categories—venomous or non-venomous. We manipulated the intrinsic value of the broader category, with half the participants being shown the venomous/non-venomous distinction (high value) and the other half being shown a low-value tropical/non-tropical distinction. Whether or not a snake is venomous could be highly self-relevant and crucial to survival, and therefore has high intrinsic value; whether a snake hails from the tropics is a much less salient, and arguably less intrinsically valuable, distinction. Will people learn intrinsically-valuable survival-relevant information, especially if this learning competes with an extrinsic goal to learn snake genera?

Method

Participants and Design

One hundred and sixty-six participants (81 male, 83 female, 2 undisclosed; age range = 18-65, mean age = 33.17) were recruited via Amazon Mechanical Turk and compensated $1 for their participation. Four participants (three from the high intrinsic value condition) were excluded from the analyses because they had relevant and correct prior knowledge about the distinction between venomous and non-venomous snakes (e.g. they identified at least one of the snakes from our stimuli set, or reported knowing that venomous snakes had slit eyes, diamond-shaped heads, or thicker bodies).

The design of the experiment was a 2 (study instruction: focus on broad vs. specific category) x 2 (intrinsic value of broad category: high vs. low) between-subjects design.

We collected data from 82 participants (judged to be a sufficient sample size to achieve power = .80, based on a medium effect), and found the reported pattern of results (including a significant interaction for genus classification). For replication purposes, we repeated our study with another set of 84 participants and obtained the same pattern of results. We thus decided to report the data in two ways: combining the data from the two experiments, using results from a 2x2 ANOVA, and meta-analyzing the two samples, reporting the separated and the pooled-analysis results.

Materials

The experiment was created using Collector (http://github.com/gikeymarcia/Collector), a PHP-based open source experiment program and administered over the Internet through Amazon Mechanical Turk.

The materials consisted of 108 pictures (60 shown during study, 48 during test) of snakes belonging to six different genera. The six snake genera consisted of three venomous (*bothrops, bitis, porthidium*) and three non-venomous (*eryx, pituophis, epicrates*) genera. Participants viewed ten exemplars of each genus during study and eight new exemplars from each genus during the test.

The snake genus constituted our specific level. Participants were presented with simplified versions of genera names. In the high-value condition, the broad classification was based upon whether each genus was venomous (labeled "*throp", "bitis"*, and "*port"*) or non-venomous (labeled "*arix", "pituo"*, and "*crat"*); in the low-value condition, the labels "venomous" and "non-venomous" were replaced with "tropical" and "non-tropical," respectively.

Visually, there were distinctions between the venomous and non-venomous (or, in the low-value condition, tropical and non-tropical) snakes that could be learned. As illustrated in Figure 1, the venomous snakes had thicker and shorter bodies, more patchy (vs. defined) patterns, arrowhead-shaped (vs. spoon-shaped) heads, and slit (vs. round) pupils. We did not choose rattlesnakes or cobras, given their familiarity, and we did not select coral snakes, given that they violate these characteristics of venomous snakes.

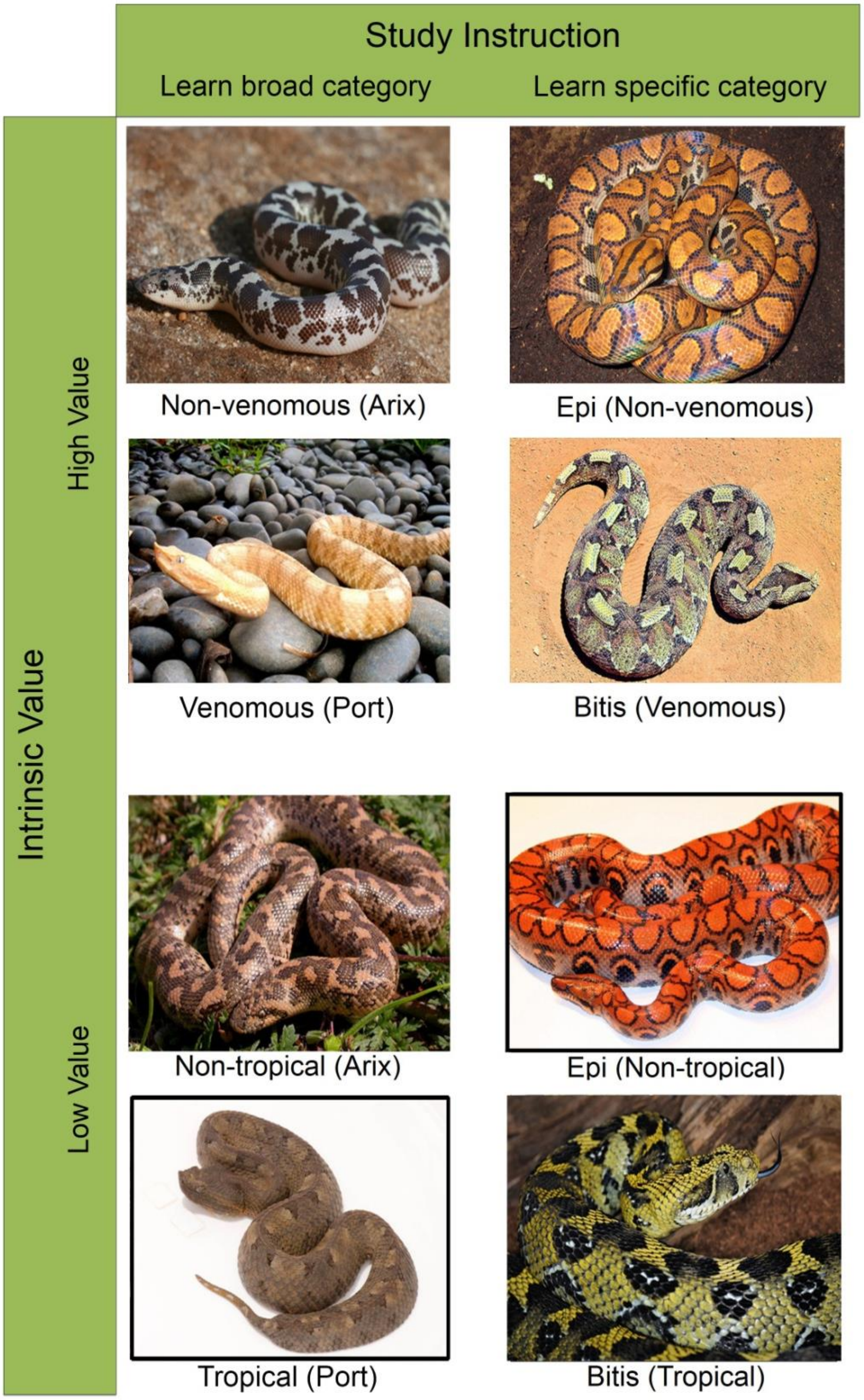

Figure 1. Sample snake stimuli, as they appeared on screen to the participants. Participants were instructed to learn either the specific (genus) or the broad (venom or tropical) information during the study phase. Value of the broad category (high = venomous/nonvenomous; low = tropical/nontropical) was also manipulated between-subjects.

Procedure

Participants were informed that they would study pictures of snakes, each labeled with the specific snake genus and its broader category. A given participant was asked to learn either the genus or the broader venomous/non-venomous (or tropical/non-tropical) categorization, for the purposes of a final test during which they would have to classify new snakes in terms of the learned categorization. The participants were then shown 60 images sequentially in a block-randomized order (ten blocks of six images, one per genus), at a rate of five seconds per image. The images were presented centrally, with both the specific and broad category labels directly below the image. When participants were instructed to focus on the specific genus, the genus name was written on the left, with venomous/non-venomous or tropical/non-tropical written on the right in parentheses. This ordering was reversed when participants were told to focus on the broad category (see Figure 1).

The final test phase consisted of two blocks, each consisting of 24 new images. In one block, participants were asked to select the genus of the snake picture from a list of genus names, regardless of the categorization they had been asked to learn. In the other block, participants were asked to identify the broad category, again independent of the categorization they had been asked to learn, and the order of test blocks was counterbalanced across participants.

After the final test, participants responded to a series of post-test questions regarding the experiment. The questions were used to assess any problems that may have occurred during the experiment as well as provide insight on individual differences and strategies. In addition, participants were asked to 1) list any distinctions between venomous/non-venomous snakes that they already knew, 2) to list any snakes that they were familiar with prior to the study, and 3) to list any snakes they knew or recognized during our study. These questions in particular allowed us to eliminate participants with prior knowledge about the snake classifications.

Results

We analyzed the data in two ways. Combining the data from the two samples, we conducted a two-way between-subjects analysis of variance (ANOVA) to examine the effects of study instruction and intrinsic value. We also conducted a meta-analysis, treating the two samples as two separate experiments.

Combined Samples Analyses

The main results are presented in Figure 2. Across all conditions, average classification performance was significantly above chance, *p*s $< .05$, indicating that regardless of whether people were instructed to learn the genus or the broader category, they were able to learn something about both levels of categorization.

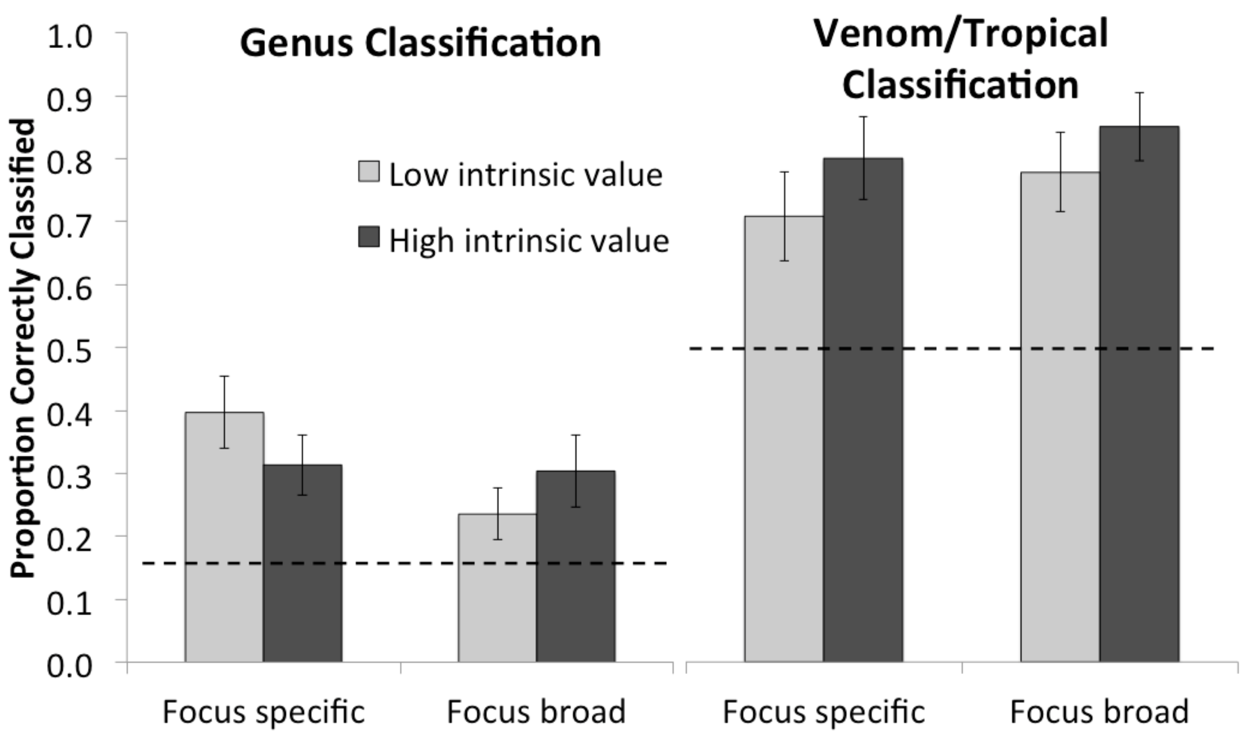

Figure 2. Specific category (genus) and broad category classification performance by study instruction and high (venomous/non-venomous) and low (tropical/non-tropical) intrinsic value. The dotted lines represent chance performance (.17 for genus classification and .50 for venom/tropical classification). Error bars represent 95% confidence intervals.

Specific category (genus) classification. The proportion of correctly classified genera, by intrinsic value and study instruction is shown in the left panel of Figure 2. People were overall better able to identify a snake genus when they were told to focus on the genus than when they were told to focus on the broader category (whether venomous/non-venomous or tropical/non-tropical). A two-way study instruction x intrinsic value between-subjects analysis of variance (ANOVA) confirmed that there was a significant main effect of study instruction, $F(1,158)= 10.66$, $MSE = .03$, $p < .01$, $\eta_p^2 = .06$, which showed that participants were better at identifying the genus when they were told to focus on the genus ($M = .36$, $SD = .17$) than when they were told to focus on the broader category ($M = .27$, $SD = .17$).

This main effect, however, was qualified by a significant interaction, $F(1,158) = 8.37$, $MSE = .03$, $p < .01$, $\eta_p^2 = .05$. When participants were asked to focus on the genus, their ability to learn the genera was impaired when the broader labels were of high-value (i.e., survival-relevant venom labels; $M = .31$, $SD = .15$) compared to when they were of low-value ($M = .40$, $SD = .19$), $t(76) = 2.17$, $p <. 05$, $g = .48$. When participants were asked to focus on the broader category, however, specific genus classification was marginally better in the high-value condition ($M = .30$, $SD = .19$) than in the low-value condition ($M = .24$, $SD = .14$), $t(82) = 1.91$, $p = .06$, $g = .41$. There was no significant main effect of intrinsic value, $F < 1$.

Broad category classification. The right panel of Figure 2 displays the proportion of correctly classified broad categories, by intrinsic value and study instruction. A two-way study instruction x intrinsic value between-subjects ANOVA showed two significant main effects: People were better able to identify the broad category when the labels were of high intrinsic ($M = .79$, $SD = .16$) than when they were of low intrinsic value ($M = .71$, $SD = .18$), $F(1, 158) = 8.67$, *MSE* = .03, $p < .01$, $\eta_p^2 = .05$, and when they were told to focus on the broad category (*M* = .78, *SD* = .17) than when they were not (*M* = .72, *SD* = .18), $F(1,158) = 4.59$, *MSE* = .03, $p < .05$, $\eta_p^2 = .03$. There was no significant interaction between study instruction and intrinsic value, $F < 1$.

Meta-analyses

We conducted meta-analyses using the ESCI software package (Cumming, 2014). The forest plot and pooled analysis graphs for the meta-analyses are represented in Figure 3.

Specific category (genus) classification. When participants were instructed to focus on learning the specific category (i.e., genus), they classified snake genera significantly better in the low-value condition (M = .40, SD = .18, 95% CI [.29, .52]) than in the high-value condition (M = .31, SD = .14, 95% CI [.26, .35]); *averaged raw mean difference* = -.081, 95% CI [-.15,-.01], *p* = .03. On the other hand, when participants were instructed to focus on learning the broad category, they were significantly worse at classifying snake genera in the low-value condition (M = .23, SD = .13, 95% CI [.19, .27]) than in the high- value condition (M = .31, SD = .18, 95% CI [.25, .36]); *averaged raw mean difference* = .076, 95% CI [.01, .14], *p* = .02. In other words, while participants were better able to classify genera in the low-value condition when instructed to focus on the genera, we observed patterns of results that were significantly different in the opposite direction when they were told to focus on the broad category.

Furthermore, heterogeneity of the effect sizes was not statistically significant, indicating that the observed effects across the two samples of participants were not significantly different from each other (low-value condition: $Q(1) = .87$, $p = .35$, $I^2 = 0.0\%$; high-value condition: $Q(1) = .31$, $p = .58$, $I^2 = 0.0\%$).

Broad category classification. When participants were told to focus on learning the genus, the high-value condition participants (M = .77, SD = .18, 95% CI [.71, .82]) classified the broad category significantly better than those in the low-value condition (M = .69, SD = .16, 95% CI [.64, .74]); *averaged raw mean difference* = .09, 95% CI [.01, .16], p = .03. Similarly, when participants were told to focus on learning the broad category, those in the high-value condition (M = .82, SD = .15, 95% CI [.78, .87]) correctly classified the broad category marginally significantly more often than those in the low-value condition (M = .75, SD = .17, 95% CI [.70, .80]); *averaged raw mean difference* = .07, 95% CI [-.002, .14], *p* = .058.

Again, there was no statistically significant heterogeneity in effect sizes in either the "focus genus" condition, $Q(1) = .04$, $p = .85$, $I^2 = 0.0\%$, or the "focus broad category" condition, $Q(1) = .56$, $p = .46$, $I^2 = 0.0\%$.

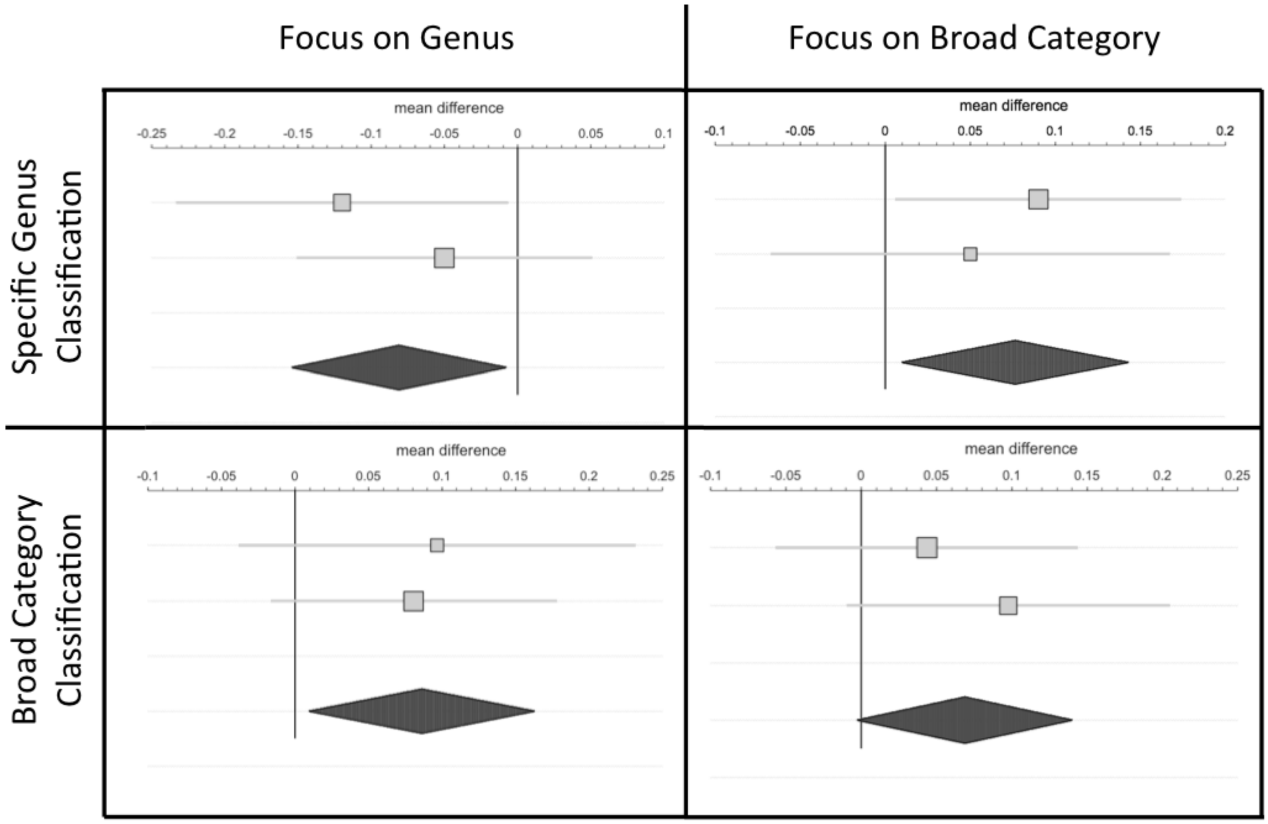

Figure 3. *Results of our meta-analyses investigating the mean difference between high and low intrinsic value conditions across all four study/test conditions. In each of the graphs, the two horizontal lines represent 95% confidence intervals of sample 1 (N = 80) and sample 2 (N = 82), respectively. The position of the squares represent the mean, while the size of the square represents the weighting of each sample in the meta-analysis. The diamond represents the summary statistic for the mean difference.*

Discussion

Overall, and not surprising, our participants were better at learning a particular level of categorization when instructed to attend to that level. Of more interest, and consistent with Nairne's theory of survival processing, as well as with prior research on value-effects in memory, a survival-relevant categorization (venomous/non-venomous) was learned more effectively than was a survival-irrelevant categorization (tropical/non-tropical). Effects from the survival-relevant category, however, may also be due to self-reference: from any individual's perspective, venomous categories of snakes are more important than whether they are tropical or non-tropical (Cunningham, Brady-Van den Bos, Gill, & Turk, 2013; Rogers, Kuiper, & Kirker, 1977; Symons & Johnson, 1997).

Moreover, when the genera labels were central to the task, specific genera identification was impaired by the presence of the broad high-value venomous/non-venomous labels, as evidenced by the interaction between study instruction and intrinsic value of the broad categories. This result suggests that the task-irrelevant venom labels captured attention and impeded learning of the genera, but any simple attention-allocation interpretation is challenged by the finding that participants learned the snake genera better if they were focused on learning venomous/non-venomous snakes than if they were focused on learning tropical/non-tropical snakes.

Why might the presence of venom labels have enhanced the learning of task-irrelevant and neutral-valued genus labels? One potential mechanism is that the snake genera labels might bind to the highly arousing venomous/non-venomous labels, but not bind to the neutral tropical/non-tropical labels. Mather and Sutherland (2011), for example, propose the arousal-biased competition theory, arguing that arousal enhances memory items with the highest priority (e.g. snake venomness), and reduces memory for those with lower priority. While these dynamics often lead to a memory narrowing effect, impairing peripheral details, they can also lead to within-object binding, enhancing associative memory for features of high priority items. If we consider the two labels (i.e., genus and broad category) to constitute one object, then the genus labels may have "bound" to the high-priority venomness labels. Specifically, in our design, given that both broad and specific categorical information corresponded to each snake picture, high-priority venomness labels could have been bound to the specific genus label, in effect overwriting the specific genus within the memory trace to only include whether or not the snake was venomous. Thus, when those participants who were instructed to learn the broad category label were tested on the more specific category (the genus), they were unable to identify the specific genus, but knew which three genera fell into each of the two venomness categories. Since each venomness category contained three snake genera, if these participants had bound genus labels to the broad category labels (i.e., bitis, pituo, and throp as venomous), “chance” would represent one out of three (i.e., guessing from the three venom-appropriate genus labels), rather than one out of six (i.e., the total number of genera studied). That they would be guessing from among the three labels follows from the notion that what has been encoded are the features that distinguish venomous from non-venomous snakes, not the features that distinguished the three venomous snake genera from each other.

To examine whether this binding speculation is plausible, we analyzed participants’ performance on the genus test relative to a chance level based on a binding assumption. Consistent with that speculation, the identification of genera when participants had been asked to learn to categorize venomous/non-venomous snakes (30.4%) did not differ significantly different from 33%, $p > .05$, whereas the identification of genera by participants asked to learn the tropical/non-tropical distinction (23.5%) was significantly worse than 33%, $t(42) = 4.64$, $p < .001$, $g = .71$. The reduced ability to identify genera after focusing on the tropical/non-tropical distinction follows from the idea that the genera labels were not bound to the tropical distinction, meaning that participants could eliminate fewer labels at the time of the final test.

In order to further evaluate the binding hypothesis, we looked at the pattern of errors within the high-value, “learn broad category” instruction condition (participants who had been asked to learn to categorize venomous/non-venomous snakes) and calculated a goodness-of-fit chi-square (χ^2) to test the frequency of genus identification errors that fell “within” versus "outside" the correct broad (venomous/non-venomous) category. We found that participants' responses were not equally distributed across both types of broader categories; rather, incorrect genus responses were found to be overwhelmingly based within the correct broad category, $\chi^2(1) = 15.16$, $p < .001$. Taken together with the performance analysis, this error analysis provides further support for the binding hypothesis.

Concluding Comments

To our knowledge, our study is the first to demonstrate the effects of value in a category-learning paradigm. Although previous research investigating value on learning has specifically investigated subsequent memory, our study advances this field by demonstrating that such value effects extend to categorizing non-studied members of learned categories. Additionally, the present study is novel in that it demonstrates that people can incidentally extract higher-order category information (e.g., venomous/non-venomous) when studying lower-order category examples (e.g., different snake genera), and vice versa, in a task that has strong ecological validity, using perceptually-rich stimuli. Finally, our results suggest that an intrinsically valuable, survival-related feature (i.e., venomness) can affect category learning in a surprising way: competing with and impairing the intentional learning of other, non-survival relevant information (e.g. snake genus), but enhancing the incidental learning of these same features. Given that most learning is comprised of a combination of intrinsic (e.g., personal preferences) and extrinsic goals (e.g., passing exams), these results illustrate the importance of understanding the ways in which competing and compatible extrinsic and intrinsic goals affect learning.

Author Contributions

S. M. Noh and V. X. Yan developed the study concept, and developed the study design together with R. A. Bjork. Testing, data collection and data analysis were performed by S. M. Noh and V. X. Yan, and the data were interpreted under the supervision of A. D. Castel and R. A. Bjork. S. M. Noh and V. X. Yan drafted the paper, and M. Vendetti, A. D. Castel, and R. A. Bjork provided critical revisions. All authors approved the final version of the paper for submission.

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