You can sweat the small stuff, too: Abstraction subordinates perceptual salience to the larger goal in a category learning paradigm

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Abstract

Three experiments investigated the role of conceptual abstraction in category learning. We found that people in a low-level mindset over-weighted global features in classifying novel exemplars whereas those in a high-level mindset did not (Experiments 1 and 3). The effect was on the learning process, independent of perceptual response preference (Experiment 3) and occurred despite evidence of perceptual global dominance for all groups during learning (Experiments 2 and 3). We conclude that abstraction can subordinate perceptual salience to the larger goal, integrating discrete encounters into a comprehensive representation of the underlying structure.

Keywords: Abstraction; Category Learning; Global precedence; Holistic primacy; Configural processing

Introduction

While the two instruments pictured in figure 1 appear remarkably similar, the one on top is a bass and the bottom one is a guitar. When we view an object, perceptual salience can lead us to focus on global or configural properties, like shape and symmetry. But while you can sometimes distinguish a guitar from a bass by shape alone, this isn't always the case. If we shift attention to the local or component features, however, we find that the bass has four thicker strings while the guitar has six thinner ones. Although this rule is not perfectly predictive either, learning the typical values on both global dimensions like shape and local dimensions like number of strings helps us to construct a more accurate representation of the category structure.

Sometimes, when encountering new objects in the world, a learner needs to overcome perceptual bias in order to comprehend the deeper category structure. How is this accomplished in the absence of explicit instruction? One possibility is that an abstract processing style—a high-level mindset—might facilitate forming a bias-free, decontextualized representation of the category structure because abstraction identifies and retains central features while minimizing incidental (or non-diagnostic) features (Trope & Liberman, 2010).

Mental representations that vary in level of abstraction are the focus of several important theories including action-identification theory (Vallacher & Wegner, 1987) and construal level theory (Trope & Liberman, 2010). Abstract representations (high level) are characterized by a greater degree of simplicity and structure; they are decontextualized and goal-relevant. Concrete representations (low level), on the other hand, are more detail-oriented, contextualized, and goal-irrelevant. Fujita et al. (2006), for example, demonstrated that participants who first generated superordinate category labels for 40 objects (high level) later favored describing everyday situations, e.g., recycling, with abstract descriptions such as "caring for the environment." Conversely, people who generated subordinate category labels (low level) more often specified concrete, low-level descriptions such as "bagging paper, glass, and cans."

Figure 1. Despite the striking similarities in shape, the bass (top) can be distinguished from the guitar (bottom) by number and thickness of strings.

Copious studies have investigated the effects of abstraction on the mental representation of individual objects or events, but the effect on a series of meaningful encounters is less clear. Does it matter if we approach *learning* from an abstract or concrete mindset? Recent studies suggest that abstraction can facilitate performance in some problem-solving tasks. Schley and Fujita (2014), for example, found that participants were more successful at representing verbal math problems in numeric form when they were in an abstract mindset.

We propose that an abstract mindset can overcome the effects of perceptual salience in service of a larger conceptual goal. Sometimes organizing and understanding the information learned from an encounter with the world may require attention to concrete perceptual details, even when the global configurations are more salient. Under these circumstances, high-level conceptual abstraction could reduce reliance on perceptually salient aspects.

Experiment 1

Global or configural properties like symmetry are generally processed faster than local or component features like texture. In the classic demonstration of global precedence, Navon (1977) asked participants to respond to the sound of a spoken letter name (e.g., F or H) by selecting that letter on a keyboard while viewing a hierarchical letter (e.g., a large F composed of smaller Hs, like the first letter in Figure 2) in which either the global (large F) or local features (small Hs) mismatched the auditory cue. It was found that when the global letter in the visual stimulus was different from the auditory cue, response latency increased. However, there was no increase in response latency for local letter mismatch.

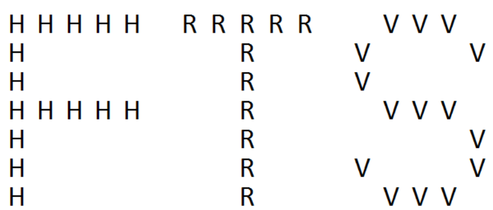

Figure 2. Hierarchical letters (exemplar from Experiment 1).

In Experiment 1, we created two categories composed of short rows of hierarchical letters like those in Figure 2. In these categories, the global (larger letters) and local (smaller letters) were equally diagnostic of category membership. We manipulated level of abstraction using a procedural priming technique and then had participants learn the categories. We assessed degree of bias toward global/local features by classification of ambiguous novel exemplars in a test phase. The global features of the ambiguous test items suggested one category while the local features suggested the other. Hence, they were statistically equally likely to belong to either category, but if people gave greater weight to one kind of feature, they would show a preference in classification.

Participants and Materials

Fifty-three New York University undergraduate students participated for course credit. After three people failed to follow instructions in the first phase, 50 participants remained for analysis (26 high level, 24 low level).

Two family resemblance categories were created, labeled 1 and 2, each containing six exemplars. Each exemplar was made up of a row of three Navon letters, resulting in six dimensions: three larger, configural letters (global) and three smaller, constituent letters (local) as in Figure 2. Each category had six letters that were typical of that category, three large letters and three small letters. The categories employed a family resemblance structure using the "one-away" design popular in much category-learning research (e.g., Hoffman & Murphy, 2006). Each exemplar had five features typical of its category and one feature typical of the other category. In this way, no feature was necessary or sufficient for categorization.

There were 18 items in the test phase. Six items featured perfectly ambiguous exemplars in which the global letters were typical of one category and the local letters were typical of the other. The remaining 12 trials were single features, i.e., the smaller letters presented individually (six trials) and the larger letters presented with the pound sign (#) as the constituent symbol (six trials).

Procedure

All instructions and responses were completed on a computer. Conceptual abstraction (CA) was manipulated using a word task developed by Fujita et al. (2006). Participants were asked to name either superordinate (high level) or subordinate (low level) category labels in response to 40 common objects; questions were phrased, "X is an example of what?" (high level) or "An example of X is what?" (low level). People in the high level group were given the example, "Singer is an example of artist"; low level was given, "An example of singer is Taylor Swift."

Next, people viewed the 12 exemplars one at a time in random order and indicated whether each exemplar was a "type 1 or type 2" by pressing the 1 or 2 keys on the computer. A large letter typical of category 1 could be made up of any of the three small letters typical of the category, and vice-versa. For example, the typical letters for category 1 were L, T, S (global), h, r, v (local). Thus, a global L could be made up of a local h, r, or v and still be typical in both dimensions. In this way, global and local dimensions remained independent, and memorization of global/local letter pairings was discouraged.

Feedback immediately followed each response. Participants performed six blocks of 12 trials each. Following each block, the computer showed their percentage of correct classifications for that block. After the learning phase, participants read that they would be performing the same task for one block without feedback. The single-feature items were also explained. The test block consisted of 18 trials presented in random order.

Results and Discussion

Twenty-six participants (52%) reached 100% accuracy in one or more of the six learning blocks. As expected, a greater proportion of high level participants achieved perfect performance (18/26 = 69%) than did low level participants (10/24 = 42%), χ^2 (1, N = 50) = 3.85, p < .05. Given that success in learning is likely to predict test performance, we included it as a variable in the analysis of test data.

We calculated a global/local score for each participant by assigning +1 for each ambiguous test exemplar categorized according to the global features and assigning -1 for each exemplar categorized according to the local features. Global/local scores were subjected to a 2 (abstraction; high, low) X 2 (perfect performance; reached, did not reach) analysis of variance (ANOVA). There were no main effects of either abstraction or performance, all *F*s < 1.4, *p*s > .24. However, the analysis revealed a significant interaction of abstraction by performance, $F(1, 46) = 4.74$, $p < .04$, $\eta_p^2 = .09$. Simple effects analyses comparing abstraction level by performance indicated that, for perfect performers, there was no difference between low abstraction ($M = -.80$, SD = 5.90) and high abstraction ($M = 1.16$), $F(1, 46) = .57$, $p > .45$, $\eta_p^2 = .01$. For participants who did not reach 100% accuracy, however, global/local scores were reliably greater for the low abstraction group ($M = 3.14$, SD = 3.57) than for the high abstraction group ($M = -1.75$, SD = 4.71), $F(1, 46) = 5.03$, $p < .04$, $\eta_p^2 = .10$, suggesting that low-level processing encouraged greater reliance on global features.

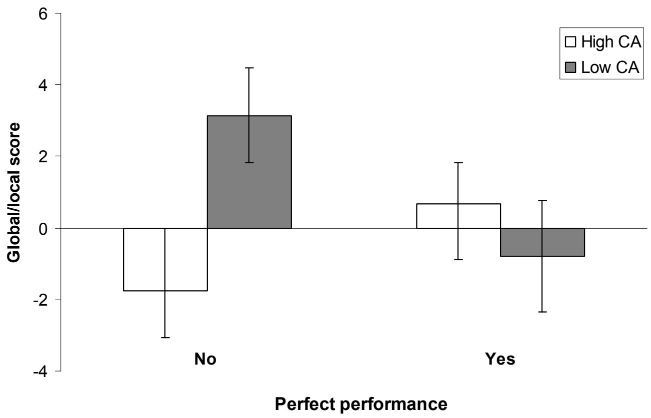

Figure 3: Mean global/local score by abstraction group and perfect performance for Experiment 1. Error bars show standard error.

In the learning phase, there were three global and three local dimensions and all dimensions were equally diagnostic of category membership. Hence, a global/local score significantly different from zero indicates a higher weighting of global (positive) or local (negative) aspects in classifying ambiguous exemplars during test. One-sample *t*-tests revealed that global/local scores of low level participants who did not reach 100% accuracy ($M = 3.14$) were significantly above zero, $t(13) = 3.29$, $p < .01$, whereas global/local scores of high level participants who did not reach 100% accuracy ($M = -1.75$) did not differ significantly from zero, $t(7) = -1.05$, $p > .30$. For perfect performers, neither group differed from zero, low level ($M = -0.80$), $t(9) = -0.43$, $p > .60$; high level ($M = .67$), $t(17) = .53$, $p > .60$.

The results of Experiment 1 support our proposal that abstraction can subordinate perceptual salience to the larger goal: For those who did not reach 100% accuracy, a concrete conceptual mindset was associated with an overweighting of global features in classifying novel exemplars, while an abstract mindset was not. Why did the effect not appear for the more successful learners? We speculate that it is a combination of a ceiling effect (perfect learners obviously know more features), and, since all participants completed six blocks, perfect learners had the opportunity to continue studying the stimuli after reaching 100% accuracy. We control for this in Experiment 3 by testing all participants immediately after reaching criterion.

Experiment 2

In Experiment 1, the assumption of global dominance was not directly tested. While it is a robust, replicable effect, global dominance can be moderated by certain visual conditions, such as duration of view and angle of exposure (Kimchi, 2015). In Experiment 2 we sought to find out if people showed an overall global dominance effect for the type of Navon letter stimuli used in Experiment 1. In order to investigate the effect of abstraction on perceptual processing independent of the learning goal in Experiment 1, we employed a task of similar length and visual complexity but one that did not require participants to integrate information across trials. Following induction, people were simply asked to "study" stimuli composed of three hierarchical letters (as in Experiment 1). At test, previously seen and novel stimuli were shown and people indicated whether they had seen them before. Novel stimuli that are similar to learned items are likely to be false-alarmed as having been previously seen. For this study, we operationally defined global dominance as greater sensitivity to differences in global vs. differences in local dimensions between previously seen and novel items. That is, memory confusions of new stimuli that differed from old ones in terms of a single global or local feature provide a measure of whether global or local differences are more important.

Participants and Materials

Eighty participants were recruited via Amazon Mechanical Turk. Five people failed to follow instructions, leaving 75 participants for analysis (37 high level, 38 low level).

Stimuli were 24 exemplars based on the two family resemblance categories used in Experiment 1. For the exposure phase, 12 prototypes were created, six using the global and local letters typical of category 1 and six using the global and local letters typical of category 2. Recall that the association of global/local letters was not held constant in Experiment 1, i.e., any typical global letter could be made up of any typical local letter. In this experiment, the order of letters was rotated such that each combination of global/local letters was used only once in the 12 prototypes. The test phase used these 12 prototypes (previously seen items) plus 12 new stimuli created using the same one-away design used in the learning phase of Experiment 1 (novel items). These stimuli were designed such that 5 of the 6 dimensions in each stimulus were typical of one category and the remaining dimension was typical of the other category. For half the items, this deviant feature was local, and for the other half, it was global.

Procedure

All instructions and responses were completed online. Participants first completed the same abstraction induction used in Experiment 1 in which they generated superordinate (high level) or subordinate labels (low level) for 40 common words. Next, they were told that they would be seeing "computer generated figures" and were instructed to study the figures carefully. There were 12 unique figures, each of which was presented twice for a total of 24 randomly-ordered trials in the exposure phase. Following exposure, people saw 24 figures, 12 of which were novel and 12 of which they had previously seen. In this test phase, the question, "Have you seen this figure before?" appeared below the image. People responded by clicking the "yes" or the "no" radio button.

Results and Discussion

Each novel item differed from a previously seen exemplar on a single dimension. If the altered dimension was global/local, then a "yes" (false alarm) indicated that the global/local difference was hard to detect. As a measure of discriminability, *d'* was calculated separately for global change items and local change items for each subject. *d'* scores were subjected to a 2 (global vs. local, within-subject) X 2 (high level vs. low level) mixed design ANOVA. As expected, *d'* for global change ($M = .77$) was significantly greater than *d'* for local change ($M = .45$), indicating that differences between novel and previously seen items were easier to detect when the change was in a global dimension, $F(1,73) = 36.54$, $p < .001$ $\eta_p^2 = .33$.

There was a trend consistent with an advantage in overall discriminability for high level vs. low level abstraction; *d'* for high level ($M = .68$) was numerically greater than *d'* for low level ($M = .54$), $F(1,73) = 2.12$, $p < .16$, $\eta_p^2 = .03$. Importantly, there was no interaction, suggesting that abstraction had no overall effect on global/local sensitivity when the task did not call for integrating information across trials, $F(1,73) = .27$, $p > .60$, $\eta_p^2 < .01$.

All groups showed global dominance, regardless of abstraction level. This is consistent with abstraction emphasizing goal-relevant features; the stated task in Experiment 2 was simply to study the stimuli, hence accomplishing the goal did not require distributed learning over the course of exposure to the exhibits as did Experiment 1. Taken together, the results of Experiments 1 and 2 support the notion that global configurations have a perceptual processing advantage and that when appropriate to the task, as in Experiment 1, high level conceptual abstraction can subordinate perceptual salience in service of the larger goal. In addition, both experiments showed a moderate overall task advantage for high-level mindsets.

Experiment 3

In Experiment 3, we set out to extend the findings in two ways. First, we varied the hierarchical dimensions of the stimuli in ways that more closely approximate the organization of everyday objects in order to extend our findings beyond the canonical—and somewhat artificial—hierarchical letters. Second, the abstraction manipulation was given to some participants before the learning phase (as in Experiment 1) and to others after learning but before test, in order to find out if abstraction truly affects learning or if it simply influences the expression of learning or response factors.

Hierarchical letters are designed to test global and local as levels by using the same forms in different roles, one as the constituent of the other. That very advantage, however, opens them up to other critiques, including that the effect may simply be due to size: the local elements are always smaller than the global configuration (Kimchi, 2015). In contrast to global/local, configural or holistic properties, like symmetry, emerge from the organization of their component parts. Everyday scenes and objects display a wide variety of configural properties such as symmetry, closure, and parallelism. Much like global precedence, configural properties have been demonstrated to show robust holistic primacy effects (Kimchi, 2015). Holistic properties such as symmetry and number of sides require looking at the whole and integrating components into a configuration; in order to judge whether one side of the figure is a mirror image of the other, one needs to take in the whole stimulus (Shuwairi et al., 2014). Thus, these function as global properties.

Color, on the other hand can function as a component (Lee et al., 2016). Like the local elements in hierarchical letters, a monochromatic color fill can be easily assessed by viewing any small portion of the stimulus. Unlike constituent letters, however, color fill can take up the same area as the configuration. Importantly, even though the *shape* that the color fills is a configural property, the *color* remains a component. Similarly, line quality of an outline, e.g., dots vs. dashes, describes a component property that can be determined from a portion of the line while it simultaneously encloses the entire figure. Thus, these features are functionally local even while relatively large.

In Experiment 3, we manipulated abstraction level using the same procedural priming technique employed in Experiments 1 and 2. The pre-learning group was given the manipulation prior to the category learning task and the post-learning group was given the manipulation after category learning but prior to test. As in Experiment 1, we assessed whether greater weight was given to configural/component features by the way people classified ambiguous novel exemplars in a test phase following learning. The test stimuli consisted of visually presented exemplars and also verbally presented sets of feature pairs. All test stimuli were constructed to be equally likely to belong to either category. In addition, we extended the learning to criterion.

Participants and Materials

Seventy-nine New York University undergraduate students participated for course credit. After removing five people who failed to follow instructions, 74 participants remained for analysis (36 high level, 38 low level; 35 pre-learning, 39 post-learning).

Experiment 3 employed a four-dimensional family resemblance structure. Two categories were created, called D and K, each composed of 4 dimensions, 2 configural and 2 component. The configural features were symmetry (symmetrical vs. asymmetrical) and number of sides (4 vs. 3). The component features were color fill (blue vs. yellow) and line quality (dotted vs. dashed) (see Figure 4 for prototypes.) Each exemplar had at least 3 features that were typical of its category. All individual features were equally diagnostic. Ten ambiguous exemplars, two visual and eight verbal, were used at test. Two visual test exemplars were created in which the configural features were typical of one category and the component features were typical of the other. Hence, these exemplars were equally likely to belong in either category. The verbal stimuli were eight ambiguous feature combinations, consisting of word pairs on a computer screen. We tested word pairs because some visual dimensions could not easily be displayed separately (e.g., one can't present a 3-sided figure without also presenting its symmetry). Because pictures have been reliably associated with concrete processing and words with abstract processing, this also allowed us to control for effects of pictorial vs. verbal information (Rim et al., 2015).

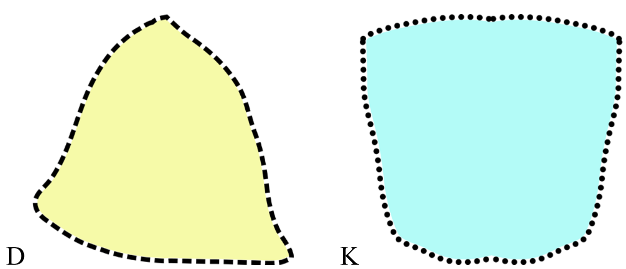

Figure 4: Category prototypes used in Experiment 3. D prototype: yellow color fill, 3 sides, dashed line, asymmetric; K prototype: blue color fill, 4 sides, dotted line, symmetric.

Procedure

The procedure was nearly identical to that of Experiment 1. Conceptual abstraction level was induced using the same manipulation as in the previous experiments. For the pre-learning condition, the manipulation was administered prior to the category learning task. For the post-learning condition, the manipulation was administered after category learning but prior to the test phase. All participants learned a single pair of categories named D and K. Each block of trials contained all 10 exemplars in random order. Learning continued for a minimum of 3 blocks; thereafter, it continued until the participant correctly classified all exemplars within the same block or until 12 blocks had been completed. Response times (RTs) were collected during learning.

After reaching criterion, participants viewed two ambiguous visual exemplars in random order followed by eight ambiguous pairs of features and eight single features presented verbally on screen, e.g., *symmetrical ... dashed line*. Participants pressed D or K to indicate their choice, without feedback.

Results and Discussion

As a measure of holistic primacy, RTs were collected for each participant's final learning block. Since all exemplars have exactly one atypical and three typical features, either the configural or the component features will be in agreement for any given exemplar. For example, if the number of sides (configural) is atypical for an item's category, then symmetry (configural), line quality (component), and fill color (component) will have typical values. In this case, the two component features are in agreement (both typical) and the configural features are in conflict. We reasoned that once the categories are known to some degree (by the last learning block), if configural processing is faster than component, then exemplars with configural feature agreement (and component conflict) should be categorized faster than those with component feature agreement (and configural conflict).

Last learning block RTs for each participant were square-root transformed, and means were calculated for configural agreement and component agreement exemplars and submitted to a 2 (feature type, configural/component; within-subject) X 2 (induction order, pre-/post-learning) X 2 (abstraction, high/low) mixed design ANOVA. We report the untransformed mean RTs for convenience. As expected, there was a main effect of feature type such that configural agreement RTs (M = 1557 ms) were reliably faster than component agreement RTs (M = 1865 ms), suggesting configural dominance overall, $F(1, 70) = 12.25$, MSE = 35.82, $p < .01$, $\eta_p^2 = .15$. There were no significant differences between inductions given pre- and post-learning, or abstraction group, and no interactions were significant, all Fs < 1, all ps > .30.

Similar to the global/local score in Experiment 1, a configural/component score at test was calculated for each participant by averaging responses in the test phase (coded -1 component, +1 configural). Configural/component scores were subjected to a 2(manipulation order; pre-, post-learning) X 2(abstraction level; high, low) ANOVA. There was no main effect of abstraction, $F(1, 70) = 1.65$, $p > .20$, partial $\eta^2 = .02$, however, there was a main effect of manipulation order, $F(1, 70) = 10.95$, $p < .01$, $\eta_p^2 = .14$, This effect was qualified by a significant abstraction by manipulation order interaction, $F(1, 70) = 4.39$, $p < .05$, $\eta_p^2 = .06$. Simple effects analyses comparing abstraction level by manipulation order indicated that, for participants who received the manipulation prior to learning, configural/component scores were reliably greater for the low abstraction group (M = 3.65, SD = 4.49) than for the high abstraction group (M = .28, SD = 5.27), $F(1, 70) = 5.48$, $p < .03$, $\eta_p^2 = .07$. For participants who received the manipulation after learning, there was no difference between low abstraction (M = 4.86, SD = 3.32) and high abstraction (M = 3.96), $F(1, 70) = .35$, $p > .55$, $\eta_p^2 = .01$.

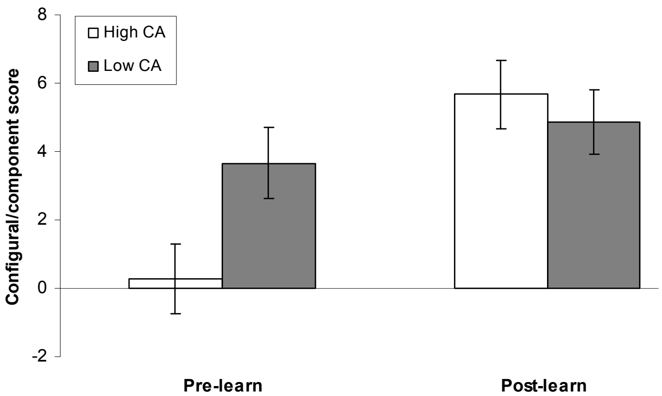

Figure 5: Configural/component score by abstraction group and pre- or post-learning manipulation.

Configural/component scores significantly different from zero indicate a higher weighting of configural (positive score) or component (negative score) aspects in classifying ambiguous exemplars during test. Importantly, only when high level was induced prior to learning were participants immune to overweighting configural dimensions, as shown in Figure 5. When the induction was given after learning, configural/component scores of both low level (M = 4.86) and high level participants (M = 5.67) were significantly above zero, $t(20) = 6.70$, $p < .001$ (low level); $t(17) = 6.08$, $p < .001$ (high level). When the induction was given before learning, low level participants also showed configural reliance (M = 3.65), $t(16) = 3.35$, $p < .01$. Critically, configural/component scores of high level participants who completed the induction prior to learning (M = .28) did not differ significantly from zero, $t(17) = .22$, $p > .80$, consistent with the results of Experiment 1.

General Discussion

Three experiments investigated the role of conceptual abstraction in category learning. We found that people in a low-level conceptual mindset over-weighted global features in classifying novel exemplars whereas those in a high-level conceptual mindset did not (Experiments 1 and 3). The effect is on the learning process, not perceptual response preference (Experiment 3). Further, this effect occurs despite evidence of perceptual global dominance for all groups during learning (Experiments 2 and 3). These findings support the theory that abstraction subordinates salience to the larger goal, integrating discrete encounters into a comprehensive representation of the underlying structure.

Factors that encourage comprehension of material rather than mere rote learning are a critical concern in education. A student, for example, may learn to translate a word problem dealing with produce in a grocery store into its numerical form yet not be able to apply the underlying principles to successfully translate a structurally similar word problem with different content, e.g., animals in a zoo (Ross, 1984). Establishing a broad, high-level mindset prior to learning could contribute to a deeper understanding of a lesson. Indeed, abstraction has been found to facilitate solving mathematical word problems (Schley & Fujita, 2014).

Future research could apply conceptual mindset manipulations in a more naturalistic paradigm, such as teaching math concepts by example. The notion that comprehension can be enhanced by a simple shift in breadth of view is an important extension of the literature on abstraction that can potentially lead to a deeper understanding of how people learn best.

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