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The Role of Imagination in Exemplar Generation: The Effects of Conflict and Explanation

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Abstract

Structured imagination refers to reliance upon prior knowledge when generating novel examples of a provided category. Yet studies supporting this tenet use experimental designs where the stimuli themselves cue exemplars based on culturally relevant items. The present study combined exemplar generation with abstract stimuli as a means of attenuating instructional bias. Participants were shown a group of abstract shapes identified as a single category and instructed to generate another member of this category. We additionally examined whether the introduction of a cognitive conflict (by including an anomalous category member) and self-explanation during generation affected the level of imaginative responses. Contrary to expectations, the presentation of a conflicting category member did not result in more imaginative responses when compared to more homogenous stimuli sets. However, a significantly greater degree of imaginative responses was observed from participants who were required to explain their thinking prior to and whilst constructing their exemplars.

Keywords: imagination; exemplar generation; cognitive conflict; self-explanation; reflective abstraction.

[Ramanujan's equations] must be true because no one would have the imagination to invent them.

G. H. Hardy

Introduction

How does imagination impact the generation of novel ideas? Theories of structured imagination assert that the generation of ideas, concepts, and objects depends on and is constrained by prior knowledge (Ward, Patterson & Sifonis, 2004). Prior knowledge limits the set of features, dimensions, relations, functions, and so on under consideration. However, support for this position comes from experimental paradigms where instructions reference prior concept knowledge or examples that cue prior knowledge. Consequently, the influence of prior knowledge on the role of imagination in, for instance, an exemplar generation paradigm remains somewhat unclear.

The exemplar generation paradigm requires participants to generate new category members that could plausibly belong to some presented set (e.g. Jern & Kemp, 2013; Ward, 1994). The paradigm anticipates that imagination behaves like other cognitive processes in requiring reasoning about the rules (or other requirements) for category membership. The empirical evidence supporting the role of prior knowledge has countered romantic views that imagination stems from some unique unobservable process. For example, Ward (1994) asked participants to draw an animal from another planet. Most responses contained features typical of Earth animals, (e.g., bilateral symmetry). Hence, knowledge from existing concepts was projected onto the generated exemplars. Evidence for the constraining effect of prior knowledge also comes from the study of cognitive biases in innovation. For instance, functional fixedness (Duncker, 1945) refers to a tendency to focus on an object's most common use. By contrast, McCaffrey & Krishnamurty (2014) argue that more novel ideas are generated when attention shifts to less frequently noticed attributes of a problem (or in our case, of the stimulus).

In the present study, we attempt to limit reliance on prior knowledge by using sets of abstract stimuli drawn from a continuous multidimensional space. The use of abstract stimuli should increase the reliance on identification of similarity between stimulus features (Tversky, 1977). For example, new exemplars generated to belong to a presented category (see Figure 1) should tend to be similar on features such as color and shape. If only perceptual features are accessible, participants would be prone to adopt *feature matching* strategies such as *replication* (e.g., copying one figure directly) or *averaging* (e.g., generating the mean of the presented examples; see Figure 1). Hence, although the use of abstract stimuli may lessen reliance on prior knowledge, the use of feature matching strategies will likely be enhanced.

The extent to which participants merely replicate or copy one of the presented category members may also depend on whether participants adopt a strong sampling assumption (i.e., that the category members were deliberately chosen as positive examples; perhaps as the only members of that category; Navarro, Dry & Lee, 2012). Under a weak sampling assumption, participants may view the presented

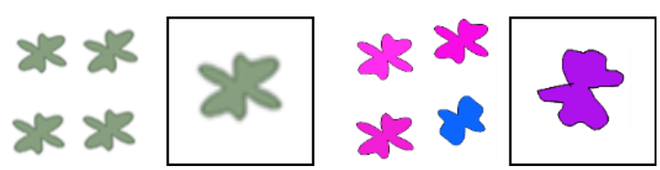

Figure 1. Examples of sets of abstract stimuli varying in perceptual features; shape, color and feature matching response strategies. Left: replication response strategy. Right: averaging response strategy. The conflict item is the blue category member. The online version is in color.

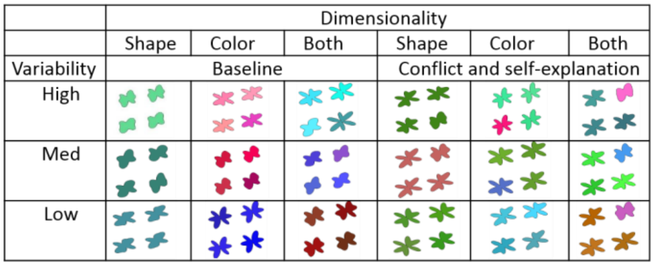

Figure 2. Examples of Stimulus Variability and Dimensionality for each instruction condition. Baseline condition: top panel. Conflict and self-explanation condition: bottom panel. The online version is in color.

category as being sampled with no restrictions; hence, the presented objects may have implicit or hidden dimensionality with unknown support (i.e., the range of values that exist for a dimension). Our first goal was to examine how variability in the presented set affected the novelty of the generated exemplars.

Ward and Sifonis (1997) varied instructions across three experimental conditions: participants were told to generate (1) an alien animal, (2) an animal wildly different from Earth animals, or (3) a living thing. The second condition produced more unusual creatures than the first condition; while diversity was largest in the third group where many responses did not adhere to standard animal features. The authors' suggested that this was encouraged through ambiguity in the instructions and by participants describing their creature prior to drawing it. A second goal of the present study was to examine whether self-explanation leads to more imaginative exemplars.

The present study aimed to examine the effects of: (i) variability of the presented category, (ii) inclusion of a conflict item, and (iii) prospective explanation and thinking aloud on exemplar generation. We compared a baseline condition to a condition which contained an anomalous exemplar and to a further condition which additionally required participants to engage in self-explanation during the generation process. Cognitive conflict is recognized as a reliable method for promoting the search for new knowledge (e.g. Limon, 2001). For example, a study conducted by Kang, Scharmann and Noh (2004) found conflict recognition promoted the invention of alternative concepts and explanations to account for the disparity caused by a conflicting stimulus. Consequently, presentation of a conflicting item may act to stimulate imagination, highlighting potential options for a new category member. For instance, an anomalous category member could highlight new dimensions from which an exemplar could be sampled.

If the underlying category rules are unclear, self-explanation may allow for exploration of alternative hypotheses through which to understand the presented

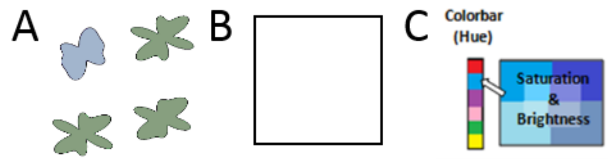

Figure 3. Example of a Single Trial. A) presented category examples, B) black box for drawing generated exemplar, C) color bar and saturation and brightness cube. The online version is in color.

category (Williams & Lombrozo, 2010). Self-explanation, has a direct influence on how objects are mentally represented and understood. Verbalisation of thought processes during an activity can enable access to cognitive processes which are not directly observable (e.g. Ericsson & Simon, 1980). Self-explanation can also override the influence of similarity, facilitate generalisation, and promote the integration of novel information with existing knowledge (Lombrozo, 2006). Similar to its influence on intelligence observed in educational psychology models which aim to accelerate cognitive development (Adey, 1992), self-explanation, therefore, affords a means of engaging imagination in order to resolve conflict.

Method

Participants

Participants were 129 University of Melbourne students who received course credit for participation. Of the participants, 16 were excluded as a result of missing data, leaving a total of 113 (91 females, M = 19.9, 3.11). Participants were randomly assigned to one of three conditions; *baseline* (n = 35), *conflict* (n = 43) or *self-explanation* (n = 35).

Stimuli

The stimuli were "blob-shaped" radial frequency curves, which varied in shape and color. Four shapes were presented, and participants were asked to generate a new member of the same category by drawing a shape using the mouse and selecting a color. In the baseline condition, the shape of the objects could vary with color identical across all of the category members; the color of the objects could vary with shape fixed, or both shape and color could vary (see Figure 2). The shape was determined by convolving three sine waves of different angles; two degrees, four degrees, and a third angle randomly generated from a normal distribution with a mean of zero and a standard deviation of 10 (low), 12.5 (medium), or 15 (high)[1].

The color was determined by selecting a starting hue from a set of fully saturated and fully bright hue values between

[1] The amplitude of the sine waves was .5, .5, and a third amplitude sampled from a normal distribution with a mean of zero and a standard deviation .1(low), .2 (medium), or 3 (high).

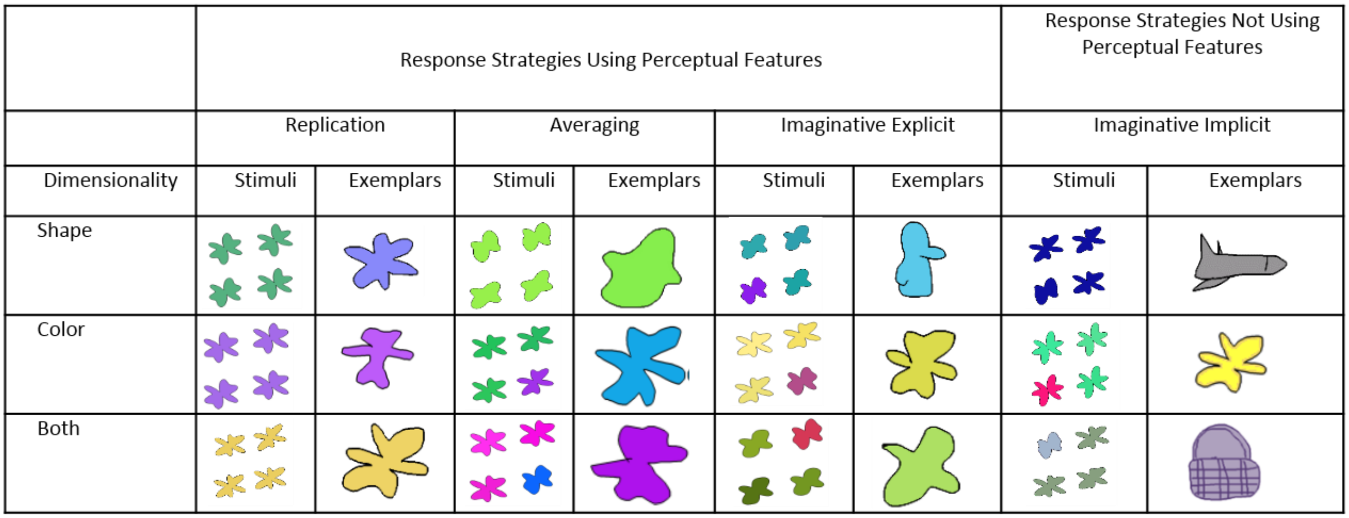

Figure 4. Coding Response Strategies. Exemplars in the black boxes are participant examples of generated responses to presented stimuli. The online version is in color.

zero and 255. These values were converted to RGB values using a look-up table. If color varied, then the hue was adjusted by a normally distributed random adjustment with a mean of zero and standard deviation of 20 (low), 40 (medium), or 60 (high)[2].

In the conflict and self-explanation conditions, three of the items had low levels of variability (as in the baseline condition), and one study item varied markedly from the other three items on shape, color, or on both dimensions (see Figure 2). The levels of conflict variation were determined in the same way as the baseline condition but with much larger standard deviations.

Procedure

Participants completed 27 trials. Each trial consisted of presentation of four items displayed on a computer monitor, with instructions indicating that the four items all belonged to a single category. Participants were instructed to use the computer mouse to draw another member of this category in the provided box and to select its color. Colors were selected by choosing a hue from a color bar and then adjusting the saturation and brightness by selecting from the shading box (see Figure 3).

In the baseline and conflict conditions, after completion of all trials, participants were instructed to provide a retrospective explanation for each trial. For the self-explanation condition, participants were asked to provide a prospective explanation and then to think aloud whilst drawing their exemplar. Prospective and retrospective verbalizations were recorded on a digital recorder.

Shape and Color Similarity Scoring To provide an objective measure of how closely the generated objects matched the presented category exemplars, we developed two measures: (1) The first method used translation, rigid shape rotation, and scaling to find the maximum proportion of overlap between the generated object and each presented exemplar. This measure ranged from 0 and 1, with 1 indicating perfect overlap. The shape similarity scores were approximately normally distributed with a mean of .61 (sd = 0.13). (2) The second method extracted the color of the generated object and computed the Delta E color difference between the drawing and each of the presented examplars (Wyszeck & Stiles, 1982). These scores were positively skewed with a lower bound at 0 (perfect color match). We log transformed these scores and adjusted the range to 0 and 1, and finally subtracted the scores from 1 so that 1 indicated a perfect color match. The final score was the minimum score across all four presented category members. The color similarity scores had a mean of .18 (sd = .07).

Expert Coding Note that our shape overlap similarity measure does not really capture the extent of creativity in the generated exemplars; nor does it capture other potentially interesting patterns of exemplar generation. To capture these patterns, we had two experts (one was the first author) classify each drawing into whether the generated object replicated one of the presented exemplars, whether the generated object appeared to be an average of the presented exemplars, or whether the generated object exhibited imaginative characteristics. This latter rating category was further broken down into cases which used the perceptual features of the presented shapes (termed *explicitly imaginative*; i.e., imaginative responses which utilized variations in blob-shape or color; e.g., a butterfly which is blob-shaped) or whether the generated exemplar drew on implicit characteristics (we term this rating category

[2] Brightness and saturation were adjusted by a similar adjustment with a standard deviation of 15 (low), 25 (medium), or 35 (high). All values were selected based on pretesting to ensure perceptibly low, medium, and high levels of variation.

implicitly imaginative; i.e., response which utilize features other than blob-shape or color; e.g., a drawing of a space ship - which may have been justified as necessary to interact with

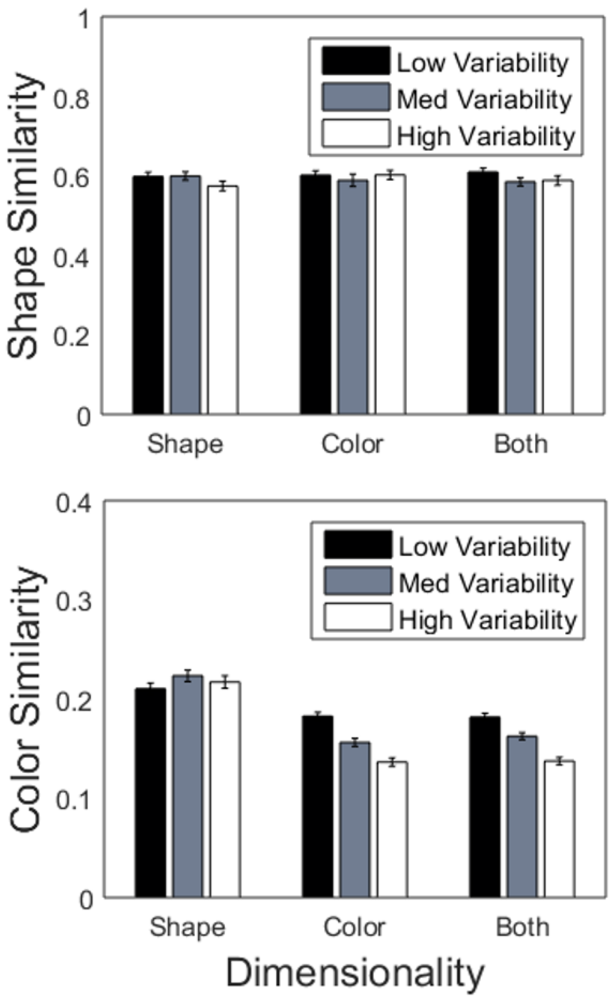

Figure 5. Average shape similarity (top panel) and color similarity (bottom panel) as a function of dimensionality and variability in the baseline condition.

the alien shapes that had been presented as part of the category). There was an 86% agreement between our expert raters; disagreements were then clarified between raters by drawing on the recordings generated by participants. Figure 4 shows exemplars representative of each response strategy.

Results

What is the effect of variability in the presented category on the generated exemplars?

We first examined the effects of dimensionality and variability within the baseline condition on both shape and color similarity. Dimensionality refers to what aspects of the presented category exemplars varied within the presented set (e.g., shape could vary with color fixed across all four category members, color could vary with shape fixed, or both could vary). Variability refers to the level of variability applied to the dimensions which were not fixed in the presented set. We examined only the baseline condition because variability in the conflict and explanation conditions was instantiated via the anomalous items and is not comparable.

Figure 5 shows that there was little effect of dimensionality or variability on the shape similarity scores. On the other hand, the color similarity scores systematically decreased with increasing variability whenever color varied in the presented set. That is, whenever the presented category exemplars varied in color, people generated colors which were more dissimilar (to the presented colors) than when color was fixed or of lower variability.

A two-way Dimensionality x Variability ANOVA confirmed these results. The largest F-ratio for the shape scores was the effect of variability, $F(2, 882) = 1.45$, $p = .23$. For the color scores, there was a main effect of dimensionality, $F(2, 882) = 151.33$, $p < .001$, a main effect of variability, $F(2, 882) = 27.35$, $p < .001$, and an interaction, $F(4, 882) = 11.06$, $p < .001$.

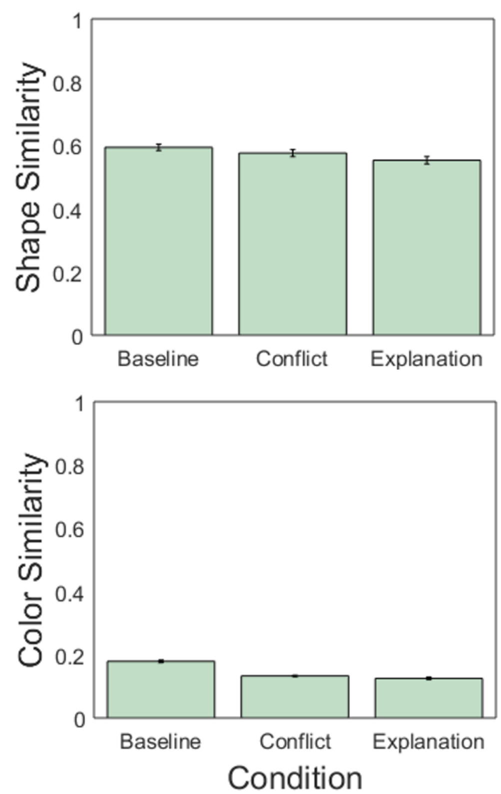

Figure 6. Average shape similarity (top panel) and color similarity (bottom panel) scores in the baseline, conflict and explanation conditions. Error bars are +/- 1 standard error.

Does conflict or explanation lead to less similar generated exemplars?

Automated Scores We compared the average shape and color scores for each participant across the baseline, conflict, and explanation conditions. There was a general decreasing trend across these conditions for both shape and color similarity (see Figure 6). Both effects were significant using a one-way ANOVA: (Shape: $F(2, 110) = 3.2$, $p = .044$; Color: $F(2, 110) = 64.05$, $p < .001$).

Expert Ratings The proportion of each drawing type is shown in Figure 7. It is immediately obvious that the main strategy for exemplar generation was to simply replicate one of the presented category members. While all conditions showed some evidence of generating imaginative exemplars, the level of implicitly imaginative exemplars appears to be higher (with a co-occurring decrease in replication) in the explanation condition. This was confirmed by a significant chi-squared test for independence across all three groups, X^2 (6) = 63.46, $p < .001$, and for the baseline vs explanation comparison, X^2 (3) = 49.11, $p < .001$, the conflict vs explanation comparison, X^2 (3) = 34.59, $p < .001$, but not the baseline vs conflict comparison, X^2 (3) = 3.02, $p = .15$.

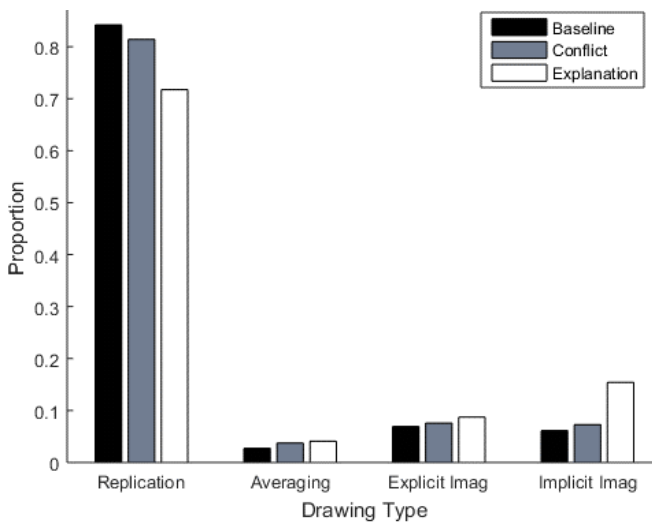

Figure 7. Expert rating proportions for the shape of the generated objects for each strategy type: replication, averaging, explicit imaginative, and implicit imaginative.

Discussion

This experiment examined the effects of stimulus variability, which included adding a conflict item to the presented category set, as well as the impact of prospective self-explanation and thinking aloud on exemplar generation.

We first showed that variability on a color dimension leads to more novel generation of values for that color dimension. We did not find an effect of variability on shape. There are a few potential explanations for this difference between shape and color similarity. For one, our operationalization of shape similarity as overlap did not adequately capture the more creative responses that were identified by our raters (see Figure 4, for examples). Second, color was easier to generate in our experiment than shape. Shape had to be hand-drawn but color could be selected from a color palatte. Hence, a third difference was that the range of color options was presented to the participant, but the range of possible shapes was unbounded. The use of a mouse instead of a stylus may have restricted the shapes that were generated; we leave this as a goal for future experiments.

We next showed that including an anomalous exemplar and allowing self-explanation, led to responses which were less similar to the presented category members. Our rating analyses clearly showed that in all conditions, replication was the most utilized strategy. Examination of the drawings revealed that most subjects drew blob like objects and that typically these blobs looked primarily like one of the presented objects. The predominant application of replication strategies in all conditions in this study may have been anticipated through our use of abstract stimuli. The use of abstract stimuli promoted the predilection toward perceptual features of the presented stimuli (Tversky, 1977), and the absence of feedback on task performance made category comprehension more ambiguous. Consequently, a replication strategy represented the simplest approach to meet task parameters, whilst requiring the least amount of cognitive effort. This result may also indicate that participants adopted a strong sampling assumption (Navarro et al., 2012) and simply sampled from the presented set.

Despite stimuli having no direct links to prior conceptual knowledge, some responses drew on knowledge external to the perceptual features of the manufactured categories. This was more prevalent when participants were encouraged to self-explain. This implies that the method of instruction, along with the method of response, plays an active role in both understanding category membership and the subsequent exemplar generation process.

Presentation of a conflicting category member did not result in more or less imaginative exemplars. The implication is that the conflict item proved difficult to assimilate, resulting in replication being favoured as a strategy. The importance of delivering a conflict at the appropriate level so as to sustain interest has been demonstrated in previous research in learning. As noted by Limon (2001), the presentation of contradictory data can only result in a meaningful conflict if it presents a challenge to existing held beliefs. If the basis of the conflict is not understood, it fails to engage the person, and therefore the conflict may be ignored or explained away (Adey, 1992). Our results suggests that conflicting items which maintain the same explicit dimensional structure might limit the recruitment of imagination. We leave it for future research to examine conflicts which signal the implicit dimensionality of the concept.

On the other hand, prospective self-explanation promoted greater use of imaginative strategies. This indicates that cognitive interaction via self-explanation can foster imaginative responses to category conflicts. It appears that self-explanation provided a mechanism for reflective abstraction of the conflict (Adey et al, 2007), and encouraged imagination to resolve the problem. In line with studies into the influence of self-explanation in dealing with anomalous data (e.g., Williams, Lombrozo, & Rehder, 2011), self-explanation encourages the greater use of imaginative strategies in response to a category conflict. It is the combination of both a conflict and a mechanism to explore the reasons behind the conflict which increases the use of imagination.

A limitation of the current study is that it failed to address whether self-explanation increases the likelihood of imaginative responses without the involvement of a conflict category member. It remains unclear whether highly imaginative responses would have arisen if a more complete range of feature variation had not been revealed by the conflict item. Therefore, repeating the current study allowing explanation in the baseline condition would facilitate a better understanding of the importance of self-explanation in promoting imaginative responses. Future studies should also explore the role of self-explanation in the use of replication. When a conflict category member was presented amongst similar stimuli, participants following a replication strategy either chose to replicate one of the three similar items or the minority conflict item. Understanding the patterns which underlies this decision making is important, as it represents the starting point for imaginative responses.

The motivation for the present study was to better understand the role of imagination in exemplar generation. To address the gap in the literature about the impact of instructions on structured imagination, abstract stimuli were used as a means of reducing access to prior knowledge when generating exemplars. Although participants favoured a strategy which leveraged perceptual features, the current study provides evidence of imaginative responses leveraging implicitly related prior knowledge. In addition, self-explanation was shown to be an effective mechanism in generating imaginative exemplars in the presence of category conflict. This experiment confirms that self-explanation makes structured imagination more flexible when interacting with unexpected categorisation tasks, and represents the starting point for greater exploration into how imagination responds to cognitive challenges.

It is worthwhile to consider how one might develop a computational model of exemplar generation. Clearly an essential mechanism is the ability to retrieve instances or features from members of stored categories and then to combine these retrieved features. This type of mechanism is reminiscent of the echo content mechanisms in Minerva (Hintzman, 1984). Our results suggest a mix of strategies which direct retrieval of one of the presented category members being the most common. The fact that replication is increased in the conflict condition suggests a role for selective attention in determining retrieval. However, in some cases, there appears to be probabilistic sampling not only of the physically presented shape and color dimensions, but also of dimensions which are implicit to the presented category and likely more conceptual than physical (see Figure 4). McCaffrey & Krishnamurty (2014) propose a taxonomy of different feature types that ranges from physical features such as size, shape, mass, weight, to the identification of object parts, to the types of functions or uses an object has, its super- and subordinate categories, associated concepts, aesthetic values, and causal relations. In this taxonomy, only certain types of features (or dimensions) are immediately available to sensory perception. Self-explanation seems to result in an increased probability of sampling from more implicit dimensions.

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