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Abstract

Labels may play a role in the formation and acquisition of object categories. We investigated this using a free-categorization task, manipulating the presence or absence of labels and whether labels were random or reinforced one of two alternative categorization cues (taxonomic or thematic relationships). When labels were absent, participants used thematic and taxonomic cues equally to categorize stimuli. When present, labels were used as the primary cue for category formation, with random labels leading participants to attend less to taxonomic and thematic relations between stimuli. When labels redundantly reinforced either thematic or taxonomic cues, the use of the cue in question was boosted along with the use of labels as a cue for categorization. Most interestingly, in spite of previously observed associations between labels and taxonomic grouping, labels did not preferentially boost the use of either taxonomic or thematic cues in comparison with the other.

Keywords: category learning; labels; thematic relations; taxonomic relations

Introduction

The role of language in object categorization has long been of philosophical and scientific interest. Labels are known to highlight similarities between category members, with redundantly correlated linguistic cues reinforcing learning of perceptual distinctions determining category membership (Yu, Yamaychi, & Schumacher, 2008; Yoshida & Smith, 2019). For example, hearing the word "dog" consistently paired with floppy ears and a wagging tail might strengthen the association of these cues with the conceptual category DOG. There is also evidence that labels boost the perceived similarity of category exemplars, such that when two perceptually distinct objects are labeled with the same word, learners adjust category boundaries to include both items (Gelman & Markman, 1986; Landau & Shipley, 2001; Plunkett, Hu, & Cohen, 2008).

Research in children mirrors results in adults. Plunkett et al. (2008) found that 12-month-olds formed a single category given a single label for a diverse set of stimuli; presented with two labels that correlated with visual cues to category membership, they successfully divided the same stimuli into two categories, but not when with randomly assigned labels. This effect of labels on category formation, whereby labels collapse low-level differences within a category while exaggerating differences between a named category and other stimuli, has been termed the "conceptual grouping effect" (Lupyan, 2008). Labels also accentuate category membership. Children, adolescents and adults all rely on perceptual characteristics when making comparisons for category membership (Sloutsky, Lo, & Fisher, 2001). However, when labels are available, young children continue to rely on overall similarity, while adults and pre-adolescents treat labels as the most predicative attribute of category membership (Sloutsky et al., 2001; Sloutsky, 2010; Deng & Sloutsky, 2013).

Labels also serve to simplify complex category knowledge. Lupyan, Rakison, and Mcclelland (2007) reported that adult participants learned classifications more quickly when they also learned names for the stimuli, suggesting that the presence of labels protect learned categories from the interference of novel stimuli. Category labels also support inductive inference (even when the label contradicts similarity information; Yamauchi & Markman, 1998) and expedite decisions about membership, resulting in more homogeneous and polarized categories (Yamauchi & Yu, 2008). Labels may further serve as "invitations to form categories" (Waxman & Markow, 1995) and may bear some of the conceptual and processing burden of the categories they represent (Connell, 2018). Linguistic information may be used to re-code non-linguistic stimuli, particularly those with a high cognitive load, such as category rules (Gleitman & Papafragou, 2005). . In fact, it is easier to learn rule-based categories if they consist of easier to name features; a compact verbal label can facilitate hypothesis formation (Zettersten & Lupyan, 2018). Labels may further help by activating the visual features that indicate category membership, aiding the processing of objects associated with them (Lupyan & Swingley, 2012). Murphy and Ross (1994) suggested that people make predictive judgments based on the most salient signifier of category membership, so it could be that the effects of labels are not unique to words, or language at all. Establishing a redundant correlation, of any type, might reinforce the strength of an association that impacts category membership. Nonetheless, linguistic cues do seem to be privileged over other cue types. Words improve categorization in comparison to non-linguistic cues, such as geometric frames (Fairchild, Mathis, & Papafragou, 2018) and associated-locations (Lupyan et al., 2007), numbers, symbols (Gervits, Johanson, & Papafragou, 2016), highly-associated sounds (Boutonnet & Lupyan, 2015) and tones (Fulkerson & Waxman, 2007). More specifically, nonsense words (Lupyan et al., 2007), consistently but not variably applied conventional words (Waxman & Braun, 2005), both arbitrary and perceptual facts (Johanson & Papafragou, 2016), and for bilinguals, ill-formed words, (Fairchild & Pa-

pafragou, 2019) all boost categorization.

Labels interact with other object features during the process of category formation. The exemplar view of categorization holds that an object is a member of that category if it is sufficiently similar to some existing conceptual exemplars (Ross & Makin, 1999). Prototype theory, alternatively, argues that category decisions are based on a hypothetical, ideal or average object – the "prototype" (Rosch & Mervis, 1975). Both theories are highly compatible with *taxonomic* organization, whereby members of a category are arranged hierarchically. Taxonomic grouping abounds in language. For example, consider the taxonomy associated with the concept "terrier". Terriers belong to the basic category of dog and dogs belong to the superordinate category of animals. Due to this nesting, members of taxonomic categories are usually clearly related perceptually, sharing a "family resemblance" (Medin, Wattenmaker, & Hampson, 1987). Moreover, taxonomic structures carry rich information to support inferences about category membership: If we know a terrier is a dog, we can assume it is an animal too.

Thematic relations, in contrast, are based on "external or complementary relations among objects, events, people, and other entities that co-occur or interact together in space and time" (Lin, 1996). Thematic categories, unlike taxonomic ones, are not related by perceptual similarity. A terrier, for example, might be thematically associated with a dog leash. This information can then be used to make inferences about the co-occurrence of objects and events. If someone is holding a leash, there is probably a dog attached to it.

Many researchers have suggested that adults favor taxonomic organizations (Ross & Murphy, 1999; Smiley & Brown, 1979; Tare & Gelman, 2010; Olver & Homsby, 1966; Imai, Gentner, & Uchida, 1994). Smiley and Brown (1979) reported that preschoolers and the elderly prefer thematic relationships, while school age children and college-age adults prefer taxonomic ones, with young children increasingly favoring taxonomic categories as they age. Recent work, however, has challenged this trend. Blewitt and Toppino (1991), Murphy (2001), and Lin (1996) failed to replicate Smiley and Brown (1979). Moreover, the latter two studies found that adults were frequently (and occasionally, dominantly) thematic (Murphy, 2001; Lin, 1996). Thematic responses persist when factors such as word frequency, association strength and co-occurrence frequency are controlled for (Simmons & Estes, 2008) and when tasks are designed to promote taxonomic understandings (Lin, 1996; Lawson, 2017). However, this is not to say that individuals are consistently thematic. Waxman and Namy (1997) found no pervasive evidence for thematic over taxonomic choices in two-year-olds.In parallel with this result, Honke and Kurtz (2019) only found an overall preference for thematicity when learning was unguided or people were specifically asked to base decisions on associativity. Thematic responding additionally became less frequent with task experience (Honke & Kurtz, 2019).It appears that adults and children rely on both methods of processing (Nguyen, 2007; Mirman & Graziano, 2012), with category creation and access dependent on particular goals (Barsalou, 1991), contexts (Ross & Murphy, 1999), and personal preference (Mirman & Graziano, 2012; Murphy, 2001). Since the proportion of thematic versus taxonomic processing depends on their relative strength in the stimulus materials (Murphy, 2001) and formal education correlates with increased taxonomic understanding (Estes, Golonka, & Jones, 2011), results supporting a thematic-to-taxonomic shift may reflect of task- or context-specific processing preferences and may be overstated in the literature (Estes et al., 2011).

Taxonomic organizations seem to be preferentially tied to labels. Markman and Hutchinson (1984) found that children shift their understanding of novel objects from thematic to taxonomic when presented with labels. People also respond taxonomically 85% of the time when instructed to select items that could share the same name (Lin & Murphy, 2001). The construction of taxonomically related words may also be prioritized during acquisition (Whitmore, Shore, & Smith, 2004). For example, while bilingual adolescents were aware of taxonomic relations between words in their native and second language, they had difficulty accessing thematic relations in their second language (Li, Zhang, & Wang, 2010). In a large free-classification task, Lawson (2017) found that participants consistently made more thematic clusters than taxonomic ones. Nevertheless, in the same experiment, the generation of single word associates to concrete object categories was largely taxonomic. Work on the interaction of labels with these different kinds of organization is more sparse.

Here we present an experimental study designed to contribute to this question. Participants completed a free categorization task, grouping a set of novel objects designed to exhibit both thematic and taxonomic relationships. In one condition, the objects were not labeled. In three other conditions, labels were introduced that reinforced thematic relationships, reinforced taxonomic relationships, or reinforced neither.Of primary interest was whether or not labels would interact differently with thematic or taxonomic cues. Given the existing literature, labels redundantly correlated with taxonomic relationships may better support category formation in comparison to those tied to thematic ones. We also predicted, in line with earlier work, that the mere presence of labels would lead participants to categorize objects based on them, with less regard for function or visual similarity.

Method

241 Participants (154 female, 86 male, one non-binary), aged between 18 and 73 ($M = 33.18565$, $SD = 12.03382$) were recruited from Prolific. All participants were native English speakers and were compensated $2 for their time.

Stimuli

A set of 18 novel objects were created using Vectr, an online vector graphics editor (Fig. 1). The stimuli were structured around six "base objects". Each base object had a *taxonomic*

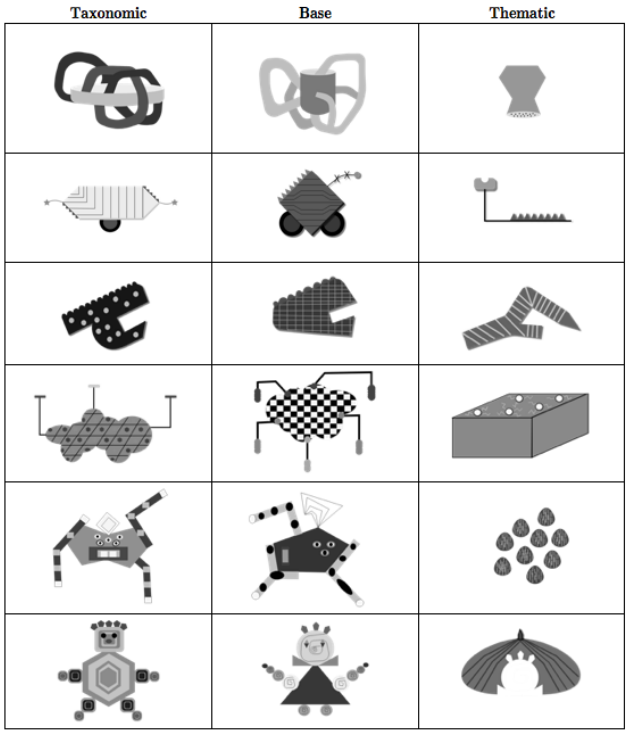

Figure 1: All stimuli objects

associate – an unfamiliar object that belonged, based on appearance, to the same superordinate category or type. Members of taxonomic pairs were similarly structured, but differentiated along several dimensions. Every base object was also paired with a *thematic associate* – an object not of the same kind as the base, but functionally related to it.

Piloting confirmed that taxonomic and thematic relations were similarly salient to participants. Participants were shown a 2×2 box containing four objects: the base object, its thematic associate, its taxonomic associate and an unrelated object. Participants were then instructed to choose two objects that went "together". For participants who picked the base object, the thematic associate ($M = 0.45, SD = 0.38$) and taxonomic associate ($M = 0.54, SD = 0.38$) were chosen equally often, $t(11.99) = 0.40, p = 0.6997$. Pilots also suggested that color provided a competing categorization cue, so all images were drawn in gray scale.

Procedure

Participants were informed that they were on a mission to an alien planet and needed to acquaint themselves with things they might encounter there. After this introduction, participants proceeded to the *familiarization phase*. This involved two subphases presented in counterbalanced order. One subphase, designed to familiarize participants with the objects individually, consisted of two slides, each featuring nine objects chosen at random from the entire stimuli set (with no overlapping objects between slides). Each slide remained on screen for 60s. In three conditions (see below) there was a box above each object indicating the word the aliens used for the object. The second subphase consisted of one slide illustrating how the base objects could interact with their thematic counterparts. The interaction slide (Fig. 2 remained on screen for 60s.

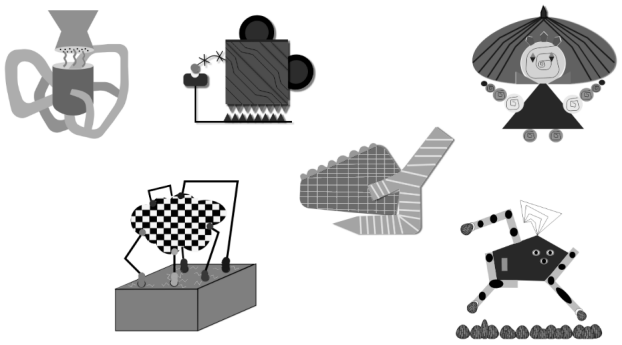

Figure 2: Interaction Subphase

Following the familiarization phase, participants began the *categorization phase*, in which they were asked to group all of the stimuli objects as they wished by dragging them into groups (of any size) on screen. Each object was presented along with its label in a gray circle of identical size. To make a group, participants were told to ensure circles overlapped.

Conditions There were four between-subjects conditions. In the *random label* condition, each object was randomly assigned one of five novel labels (*neert, ridu, urtasu, sunel, potum*), visible in both the familiarization and categorization stage. The labels were selected to not reinforce any thematic or taxonomic relations between objects. In the *thematic label* condition, thematically related objects shared the same label. In the *taxonomic label* condition taxonomic pairs shared a label. In the thematic and taxonomic conditions, objects belonging to the non-relevant organizational structure were assigned labels randomly. Finally, In the *no-label* condition there were no labels at all, including in the familiarization phase.

Analysis Groups created in the categorization task were rated based on the proportion of objects involved in taxonomic, thematic, or label-based categorizations. Objects not explicitly related to other items through one of these dominant categorizations were coded as "Other". The inclusion of objects in one organization type did not prevent the grouping of the same objects in another organization type as well. That is, if a group included an object with one label associate, and one taxonomic associate, the object was included in counts for both label-based and taxonomic organizations. In conditions where labels served to emphasize organization types, objects were counted towards both the reinforced organization and a label organization. (In the random label condition, labels were purposefully applied so that no such overlap oc-

curred.) Each participant was given a score for for each organization type, calculated as the mean of that type across all groups created.

We used R (R Core Team, 2017) and lme4 (Bates, Mächler, Bolker, & Walker, 2015) to perform a linear mixed effects analysis of the relationship between mean organization scores for each condition and organization type, with organization type as a fixed effect and by-participant random slopes. The Satterthwaite approximation of degrees of freedom was used to obtain a p-value from a t-value.

Results

Fig. 3 shows mean scores for different organization types. There was a significant effect of organization type in the random label condition ($F[3,232] = 21.6, p < 0.001$), the thematic label condition ($F[3,236] = 72.43, p < 0.001$) and the taxonomic label condition ($F[3,236] = 110.24, p < 0.001$), suggesting that the organizations inherent to the stimuli impacted participants groupings. However, this was not the case in the no-label condition ($F[2,177] = 2.37, p = 0.097$).

We conducted further analysis to investigate whether there was an interaction between categorization type and condition. A significant type $\times$ condition interaction would suggest that differences in categorization related to thematic or taxonomic relationships between stimuli were modified by the role played by the different kinds of labels. Indeed, there were significant main effects of type ($F[2,705] = 7.98, p = 0.0003$) and condition ($F[3,705] = 17.79, p < 0.001$) and a significant interaction between type and condition ($F[6,705] = 28.54, p < 0.001$). This pattern of results holds when the no-label condition is excluded.

In the random label condition, a post-hoc paired t-test found no significant difference between Taxonomic ($M = 0.25, SD = 0.26$) and Thematic ($Mean = 0.20, SD = 0.22$) organizations, $t(113.86) = 1.27, p = 0.21$. In the no-label condition, similarly, there was no significant difference between frequencies of Taxonomic ($M = 0.39, SD = 0.20$) and Thematic ($M = 0.32, SD = 0.22$) organizations, $t(117.15) = 1.92, p = 0.06$. Thus, in both the presence and absence of labels, participants generally did not favor one type of organization over others.

A planned comparison revealed that taxonomic scores in the taxonomic-label condition ($t[115.89] = -3.24, p = 0.002$) and thematic scores in the thematic label condition ($t[118] = -3.52, p < 0.001$) were higher than in the no-label condition. When labels superfluously supported existing thematic or taxonomic cues, the use of the coordinated cue was augmented relative to the no-label condition.

To disambiguate the relative effects of a label on thematic or taxonomic organizations, post-hoc tests were conducted on a reduced model containing only data from the taxonomic label and thematic label conditions. This revealed a significant main effect of categorization type, $F(3,472) = 125.71, p < 0.001$, and an interaction between categorization type and condition, $F(3,472) = 49.09, p < 0.001$, but no main effect of condition, $F(1,472) = 0.77, p = 0.38$. Likewise, an analysis of the taxonomic participant means in the taxonomic label condition($M = 0.51, SD = 0.18$) and the thematic participant means in the thematic label condition ($M = 0.46, SD = 0.22$) was not significant, $t(112.46) = 1.23, p = 0.22$. These analyses collectively reveal that labels did not differentially impact thematic or taxonomic organizations.

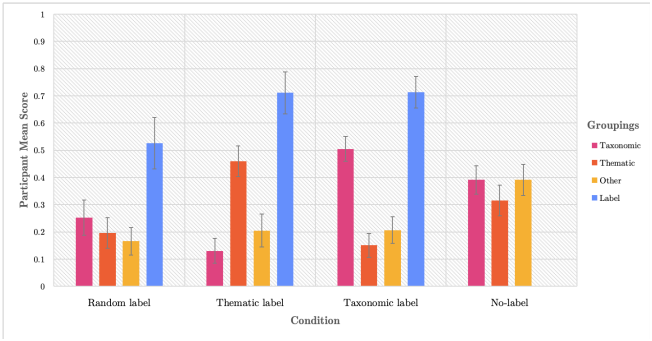

Figure 3: Means for organizational types in all conditions. Error bars indicate 95% confidence intervals

Discussion

We investigated the role of labels in category formation by asking adults to categorize novel objects. Our results replicate earlier work in two ways. First, our adult participants seem to have relied on both thematic and taxonomic relations for categorization. That is, in the absence of labels or the presence of random labels, both thematic and taxonomic strategies were used equally often. Second, we found that labels dominated categorization strategies. For all conditions in which labels were available, they were the preferred basis for categorization, boosting taxonomic or thematic categorization where they corresponded to these relations in the meaning space. Most interestingly, the inclusion of labels did not affect taxonomic and thematic relations differently. When labels corresponded to thematic relations in the meaning space, thematic categorization strategies were boosted to the same extent as taxonomic strategies were when labels corresponded to taxonomic relations.

A way of interpreting our results, consistent with (e.g.) Landau and Shipley (2001), is that labels influence the placement of category boundaries by giving participants an easily available and salient cue to categorization, encouraging them to attend less to differences and similarities between the stimuli themselves. This is evidenced in particular by the results of the random label condition, in which label-based groupings dominated even though labels did not correspond reliably to any obvious features of the stimuli, and in spite of competing cues— namely taxonomic and thematic relations between items—being built into the stimuli. It was not the case, however, that participants were simply not aware of these relations. In the absence of labels, they seem to have made use of taxonomic and thematic relations in organizing stimuli.

An interesting comparison can be made here with previous work that found that arbitrary labels disrupted category formation (Plunkett et al., 2008; Yu et al., 2008). We found that the inclusion of such labels inhibited the formation of categories along thematic or taxonomic lines but encouraged the formation of categories that were consistent with the labels. In the thematic- and taxonomic-label conditions, our findings were consistent with this work and with other work finding that redundant labels facilitate categorization according to existing taxonomic or thematic structure (e.g., Lupyan et al., 2007).

In other words, our participants used labels as the primary cue to category membership, regardless of their correspondence to existing structure (cf. Sloutsky et al., 2001). It seems therefore that labels do more than simply highlight existing cues in the meaning space. Rather, they themselves can serve independently as cues. Another way of thinking about this is that "labels serve as invitations to form categories" (Waxman & Markow, 1995), for which learners might then proceed to seek out physical or perceptual commonalities. For example, if a learner sees a chihuahua and komondor as their first instances of the named category "dog", the common physical properties of dog may not be initially recognized or understood to a sufficient degree to facilitate extension of the category. Until a true conceptual knowledge is built for "dog", the label might serve as a placeholder until the learner has enough information to generalize based on physical properties. There seem to be many categories that function like this. Many people can identify mushroom as a type of fungi, but not the specific characteristics that make it so.

However, the results of our thematic-label and taxonomic-label conditions bring nuance to this pattern. Label-based categorizations were used more frequently in these conditions than in the random-label condition, suggesting that while people may use random labels to guide category creation, labels become more attractive as cues to category formation when they coincide, and do not compete, with alternative cues. Along similar lines, thematic and taxonomic categorization were used more when redundantly reinforced by labels than when they were not. Our thematic and taxonomic labels can, in line with prior literature, be thought of as inviting physical comparison between objects, highlighting within-group similarities (Landau & Shipley, 2001), serving as a point of contrast with out-group members (Lin & Murphy, 2001), and adding redundancy to existing perceptual cues (Yoshida & Smith, 2019).

Our finding that participants did not prefer either taxonomic or thematic categorization cues, in the absence of labels, contrasts with the findings of earlier work, such as that of Smiley and Brown (1979), but is consistent with more recent literature (e.g., Estes et al., 2011).

It is particularly interesting, however, that redundant labels did not preferentially benefit either taxonomic or thematic categorization. It is somewhat unusual (at least for English-speaking participants) for thematic categories to bear straightforward labels, and earlier work suggests that people treat labels as corresponding preferentially to taxonomic groupings (Markman & Hutchinson, 1984; Lin & Murphy, 2001; Li et al., 2010). We might thus expect—contrary to our results—that labels would feel less appropriate for these categories than for taxonomic categories, leading to a difference in the degree to which taxonomic and thematic cues would be boosted by labels. One possibility is that labels invite participants to treat a thematic category as potentially taxonomic. Learners are known to interpret novel labels as belonging to basic-level category objects (Markman, 2002). For example, a speaker might assume a new word used to refer to a Yorkie means "dog", as opposed to "terrier" or "animal". In our study, participants presented with a consistent novel label might have assumed that all the thematic objects belonged to a previously unencountered taxonomic category. Alternatively, it may be that apparent inconsistencies between taxonomic organization and labels operate at a different level and are less relevant to the kind of task we gave our participants. As we found in our no-label condition, learners are known to use both taxonomic and thematic cues based on context and need (Mirman & Graziano, 2012) and the results of our label conditions may simply reflect this.

A potential limitation of our study concerns the difficulty in establishing taxonomic or thematic relations in novel stimuli. Real-world objects participate in multiple, overlapping organizational schemes, and it is in principle possible that our results represent some artifact of the experimental paradigm. However, we took various measures (including counterbalancing and piloting to ensure equivalent salience of cues) to mitigate this possibility. It is also notable that earlier work suggested two-dimensional depictions of objects might encourage taxonomic processing (Gelman, Chesnick, & Waxman, 2005). We did not find this in our own results. Nonetheless, presentation of taxonomic groupings nonetheless differed in some respects from the presentation of thematic relations; while the similar treatment of both cues by participants seems to suggest that this does not have consequences on behavior, in future work it would be interesting to investigate the role or presentation of such relationships in more detail. A further limitation concerns the structure of the meaning space we designed. For simplicity, the taxonomic and thematic relationships that we designed between our stimuli were all two-way relationships. However, the labels corresponded to larger sets of items. While it seems unlikely that this would influence the relative role of labels with respect to taxonomic or thematic categorization, it is possible that it played a role in encouraging the use of label-based cues overall. This would be important to control for in future work.

In summary our findings expand upon previous research studying the role of labels in categorization, suggesting that participants use both thematic and taxonomic cues in categorization and that random labels impact category formation. Most interestingly, redundant labels boost thematic and taxonomic organization to a similar extent.

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