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The Influence of Stimulus Properties on Category Construction

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It has been demonstrated that when people free classify stimuli presented simultaneously in an array, they have a preference to categorize by a single dimension. However, when people are encouraged to categorize items sequentially, they sort by "family resemblance," grouping by overall similarity. The present studies extended this research, producing 3 main findings. First, the sequential procedure introduced by G. Regehr and L. R. Brooks (1995) does not always produce a preference for family resemblance sorts. Second, sort strategy in a sequential procedure is sensitive to subtle variations in stimulus properties. Third, spatially separable stimuli evoked more family resemblance sorts than stimuli of greater spatial integration. It is suggested that the family resemblance sorting observed is due to an analytic strategy.

Categorization is a fundamental building block of everyday cognition; it is hard to imagine how people would function effectively without it. Categorization enables one to react to different objects in the same way and to make inferences about how novel objects should be treated. For instance, when a person sees a novel object, classifying it as a "dog" allows the person to deal with it in an appropriate manner. Because of the immense variety of discriminable objects that people encounter in the natural environment, it is necessary that this categorization process should be highly constrained, as there are virtually limitless numbers of ways in which objects can be partitioned. It is therefore of fundamental importance to understand the principles that underlie the categories that people have.

Traditional categorization experiments give the participant item-by-item specific feedback about category membership. While such an approach is undoubtedly useful in examining category learning, it seems extremely unlikely that people receive this level of feedback anywhere other than in the laboratory. One way of addressing this issue is to examine how people spontaneously categorize a group of objects. This can be done by providing them with a group of stimuli and asking them to categorize them in the way that they think is most appropriate. No feedback, or other information, is given by the experimenter. Such an approach has variously been called category construction (e.g., Medin, Wattenmaker, & Hampson, 1987), free sorting (e.g., Bersted, Brown, & Evans, 1969), and free classification (e.g., Handel & Imai, 1972).

It seems reasonable to assume that the categories we prefer to create would reflect the underlying structure of objects we encounter outside the laboratory. Over the years, there have been several influential theories of categorization. The "classical" view (see E. E. Smith & Medin, 1981, for a review) theorizes that categories are made up of necessary and jointly sufficient features. However, many thinkers (e.g., Ryle, 1951; Wittgenstein, 1958) believe that natural categories have a "family resemblance structure." Under this theory, an object does not have to possess any single item, but if it has enough features that are characteristic of that category, it can be considered a member of that group. In a family resemblance structure, within-group similarity is maximized and between-groups similarity is minimized. The family resemblance theory is commonly considered a more plausible theory than the classical view as studies have shown that many natural concepts seem to be organized around a set of characteristic rather than defining features (e.g., Mervis & Rosch, 1981; Rosch & Mervis, 1975).

Despite the plausibility of the family resemblance theory, it has been widely demonstrated that dividing novel stimulus sets into a family resemblance structure is far from common in free classification. One of the first such investigations was by Imai and Garner (1965), who used stimuli that consisted of a pair of dots varying in position, the distance between the dots, and their orientation. Categorization decisions were virtually always based on a single attribute. Imai and Garner's explanation was that although there were many ways in which these stimuli could have been grouped, by far the easiest was to group the stimuli on the basis of a single attribute.

More recently, Medin et al. (1987) demonstrated that, for a variety of different stimulus types, people show a strong preference to sort using a single dimension (unidimensional sorting), even when the instructions, stimulus characteristics, and structure were manipulated. For instance, Medin et al. varied the number of dimensions, had both binary and trinary-valued dimensions, and used both cartoonlike animals and lists of verbal descriptions as stimuli. Medin et al. (1987, p. 272) concluded "there was no evidence that subjects used overall similarity or some other means of integrating component information to construct categories." Similarly, Ahn and Medin (1992) found that unidimensional sorting dominated category constructions and concluded that people have a strong bias to create classical categories based on a single dimension. They suggested that family resemblance categories

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would only be created when people are forced to classify exemplars that are unable to be classified in the classical manner.

Regehr and Brooks (1995) extended this previous research with a number of stimulus manipulations designed to encourage family resemblance sorting. First, they increased the number of features characteristic of each category to 10. They believed that increasing the number of features would make the participant less inclined to focus on a single one of them, as they would be more aware of ignoring relevant information. It has also been suggested that increasing the stimulus complexity encourages participants to respond to overall similarity (e.g., L. B. Smith, 1981). Second, they decreased the separability of the dimensions in the stimulus set as it has previously been shown that family resemblance categorization is more prevalent for integral stimuli than separable stimuli (e.g., Garner, 1974; Handel & Imai, 1972; Lockhead, 1972). Third, one stimulus set had a simple underlying rule defining the two categories (geometric shapes that were principally angular or rounded). However, all three stimulus sets provided robust evidence that people still preferred to sort on the basis of a single dimension.

After these stimulus manipulations had again failed to produce any significant family resemblance sorting, Regehr and Brooks (1995) varied the presentation method of the stimuli. Previously (Ahn & Medin, 1992; Medin et al., 1987), all of the stimuli in the set had been presented simultaneously, which seems a rare categorization task outside the laboratory. Regehr and Brooks argued that when the whole stimulus set is presented simultaneously there is a tendency to scan across the set to look for a simple rule, making individual dimensions more obvious. They believed that if participants were encouraged to categorize each stimulus individually there would be a greater likelihood of family resemblance sorting. The match-to-standards procedure was developed to test this theory. In this procedure, two prototypical stimuli representative of Categories A and B were presented side by side on a table. Participants then had to categorize each member of the set sequentially by placing the cards into the category that they thought was most "natural." The results showed a dramatic reversal in categorization strategy, with all the stimulus sets that had previously been categorized unidimensionally now resulting in family resemblance sorts. This led Regehr and Brooks to conclude that the way that the stimuli are presented has a dramatic effect on categorization strategy, whereas the stimulus properties, in keeping with previous category construction experiments, had little effect. At the very least these results demonstrate that, in some situations, people appear to find sorting objects on the basis of all the features the "natural" thing to do. A stronger conclusion is that family resemblance sorts are the default behavior and that the unrealistic nature of the array task prevents this default behavior from being observed. Hence, the category construction data are not fundamentally at odds with the family resemblance theory of natural categories.

The stimuli used by Regehr and Brooks (1995) were all perceptually simple, highly artificial, and specifically designed to encourage family resemblance sorting. Our aim was to test the replicability of Regehr and Brooks's results within a match-to-standards procedure and then investigate the extent to which the effect generalizes to stimuli that have more in common with everyday objects.

Experiments 1–3

General Method

Participants. Participants were students of the University of Exeter, Exeter, United Kingdom, who were approached to take part in the experiments as volunteers. In each of the experiments there were 14 participants. Participants were tested individually in a quiet testing cubicle, and no person participated in more than one experiment.

Stimuli. The stimuli varied between the experiments but all had a similar structure to that used by Medin et al. (1987). This abstract stimulus set is shown in Table 1. Each stimulus set consisted of four binary-valued dimensions (D1–D4), and the stimuli were organized around two prototypical stimuli, each representative of a category. These prototypes were constructed by taking all of the positive-valued dimensions for one of the stimuli (1, 1, 1, 1) and all of the zero-valued (0, 0, 0, 0) dimensions for the other stimulus. The other stimuli in the set (one-aways) each had three of the four characteristic features of their category and one atypical feature characteristic of the other category. Sorting the stimuli by a family resemblance structure, as shown in Table 1, maximizes within-group similarities and minimizes between-groups similarities. In total, there were 10 stimuli in each stimulus set.

Procedure. The method of stimulus presentation was a slight variation on Regehr and Brooks's (1995) match-to-standards procedure. The two prototypes were laid side by side on a table, and participants were told that these 2 items were representative of two different categories (A and B). Participants were informed that they would be given 10 items that had been shuffled into a random order, which they would then have to place into the two categories. They were told that there were many ways in which the stimuli could be split and that there was no correct way to do it. The two groups did not have to be of equal sizes, but participants were not allowed to look through the stimulus set or to refer back to previous decisions. Once they had made their decision, participants placed the item face down directly below the prototype they felt it most resembled so that they could not refer back to it (in Regehr & Brooks's experiment, stimuli were placed face upward). Participants were informed that there was no time limit for the completion of this task. Once they had finished classifying the 10 items, the participants were asked to explain as precisely as possible the way in which they had classified the 10 items.

Analysis of the results. Two sources of information were used when deciding how to classify the sort strategy that each participant used: the description the participant gave as to how they had categorized the stimuli and the categories that the participant constructed. The categories that these sort strategies were placed into were closely modeled on those used in Regehr and Brooks (1995). These included the following categories.

The *unidimensional sort* is a sort strategy based on a single feature of the stimulus. It did not matter which dimension was used as the basis of sorting

Table 1
The Abstract Stimulus Set Used in All Experiments

Category							
A				B			
D1	D2	D3	D4	D1	D2	D3	D4
1	1	1	1	0	0	0	0
1	1	1	0	0	0	0	1
1	1	0	1	0	0	1	0
1	0	1	1	0	1	0	0
0	1	1	1	1	0	0	0

Note. Each row (within each category) describes a different stimulus. D = dimension; 1 and 0 represent the values of each dimension.

as long as all of the positive-valued dimensions for the chosen feature were in one category and all of the zero-valued dimensions were in the opposite category.

Sorts were placed into the *one-away unidimensional sort* category if participants' descriptions were that they had classified on the basis of a single feature but there was a solitary error in their classification strategy. In other words, nine of the items were classified on the basis of a single feature but the other item was placed in the wrong category.

Sorts in the *family resemblance* category had the identical structure to that shown in Table 1. This means that sorts were classified as family resemblance if each of the prototypes along with their derived one-aways were placed in separate categories without error. Additionally, the participants had to describe their strategy as either being based on general similarity or by indicating that they placed each item into the category with which it had more features in common.

The *one-away family resemblance sort* is similar to the one-away unidimensional sort with the exception that the error occurred in a sort that was otherwise family resemblance.

Any other category sorts were placed into an *other* category, even if the description given by the participant fitted one of the sorts described above.

Experiment 1

Method

Experiment 1 was a replication of Experiment 2a of Regehr and Brooks (1995) and examined whether the match-to-standards procedure is robust to our slight change in procedure and a different participant population. In this stimulus set (shown in Figure 1) one group is characterized by angular features and the other by rounded features.

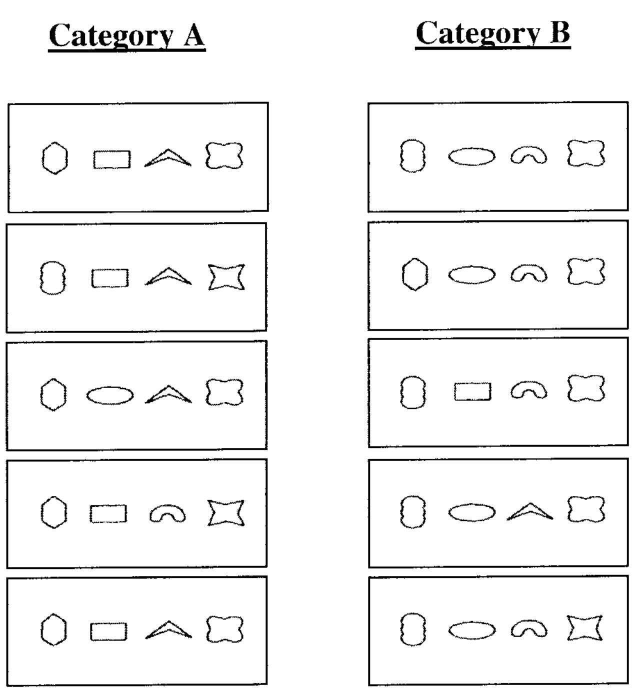

Figure 1. The stimuli used for Experiment 1, grouped by a family resemblance structure. Each prototype consists of four geometric shapes in a fixed position. Category A is characterized by angular features and Category B by rounded features. Each category consists of one prototype and four items that have three features characteristic of their category and one atypical feature.

Results and Discussion

The results of Experiment 1 are shown in Table 2. Regehr and Brooks's (1995) finding was replicated; a strong preference for family resemblance in a sequential procedure was found. One difference was that the individuals in our experiment were not as accurate as those in Regehr and Brooks's study. This is demonstrated by the relatively high amount of one-away classifications in our study. Nevertheless, the results of our experiment provide further evidence that the match-to-standards procedure can support a robust preference for family resemblance sorting.

Experiment 2

Method

Although Experiment 1 establishes the robustness of Regehr and Brooks's (1995) finding with the same stimuli they used, one might argue that the generality of their conclusions is limited by their choice of a highly artificial, perceptually simple collection of elements. We attempted to assess the generality of their conclusions by attempting to replicate the effect with perceptually difficult, spatially integrated stimuli that were arguably more like everyday objects. The stimuli were schematic butterflies (shown in Figure 2) and had four variable features: the size of the antennae, the size of the body, the hue of the lower part of the wings, and the quantity and size of the dots (controlled so that each type has an equal amount of black ink). Both categories possessed characteristic features: Category A was characterized by small antennae, a larger body, wings of a darker blue, and fewer dots, and Category B by large antennae, a smaller body, wings of a lighter blue, and more dots.

Results and Discussion

Contrary to our expectations, the results of Experiment 2 (shown in Table 2) show a clear tendency for people to categorize this stimulus set unidimensionally. The difference between the sort strategies used for Experiments 1 and 2 was significant, $\chi^2(2, N = 14) = 12.272, p < .01$.[1]

The clear implication is that the match-to-standards procedure does not always result in family resemblance sorting. The stimuli used did not have any dimension that was particularly more salient than any of the others, or at least there was no significant preference for any single feature in unidimensional sorting, $\chi^2(3, N = 14) = 2.00, p > .05$, which could have been a potential explanation for the results. Because of the small sample size, though, this conclusion should be treated with some caution. The stimuli used were, however, more spatially integrated than have been used in previous category construction studies and the perceptual discriminations involved arguably less easy. This result is all the more interesting as it has been demonstrated under a procedure that has previously evoked a strong preference for family resemblance sorting. These results indicate that the sort strategy used can be influenced by the type of stimulus to be categorized: two different types of stimuli, with the same instructions and procedure, have

[1] No corrections have been applied for the low expected frequencies of some of the cells. It has been found that even small expected frequencies do not increase the chance of Type I errors (Bradley, Bradley, McGrath, & Cutcomb, 1979). No corrections have been applied for any of the future analyses involving small expected frequencies. A general discussion of this issue can be found in Howell (2002, pp. 151–152).

Table 2
Sort Strategy Frequencies for Experiments 1–3

	Sort Strategy						
	UD sort			FR sort			Misc.
Experiment and stimuli	1-away UD	UD	Total UD	1-away FR	FR	Total FR	Other
Experiment 1 (geometric shapes)	1	0	1	4	7	11	2
Experiment 2 (artificial butterflies)	5	5	10	1	2	3	1
Experiment 3 (artificial butterflies with matching pairs task)	0	10	10	0	3	3	1

Note. UD = unidimensional; FR = family resemblance.

resulted in markedly different category construction preferences. This is in contrast to Regehr and Brooks's finding that sort strategy was remarkably robust to stimulus type in an array procedure.

Experiment 3

Method

As the stimuli in Experiment 2 were arguably perceptually difficult, it is possible that participants concentrated solely on the first feature pair that they identified and based their strategy on this alone. Consequently, it is possible that people had not identified all of the other features, making a family resemblance sort impossible. In Experiment 3, a presort procedure was introduced to address this potential concern. Before participants were introduced to the sorting task, 20 artificial butterflies were spread out randomly in an array in front of the participant. These 20 butterflies consisted of the 10 stimuli used in Experiment 2 and an identical copy of each of these butterflies. The participant had to match these 20 stimuli into the 10 identical pairs correctly without feedback. When the participants felt they had matched the pairs correctly, these pairs were then examined, and if there were any mistakes, they then had to match all of the pairs again. To do this task correctly, the participants not only had to have identified all of the different dimensions but also had to make use of them all, otherwise they could not complete the task successfully. After the participants had completed this task, the stimuli and procedure for the sort phase were identical to Experiment 2.

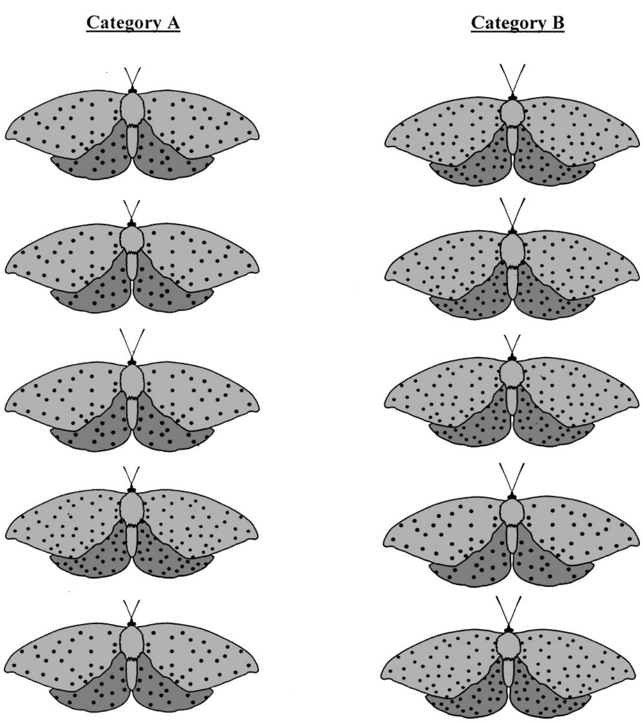

Figure 2. The stimuli used for Experiment 2, organized into their family resemblance groups. Each category consists of one prototype and four items that have three features characteristic of their category and one atypical feature.

Results and Discussion

The overall number of family resemblance and unidimensional sorts produced in Experiment 3 was identical to Experiment 2 (see Table 2). There was no significant preference for any particular feature in unidimensional sorting, $\chi^2(3, N = 14) = 4.4$, $p > .05$, but this conclusion should again be treated with some caution because of the small sample size. The only effect that the extra exposure to the stimuli had was to make the participants more accurate in carrying out their intended strategy. A chi-square was performed investigating the differences in strategies carried out correctly (unidimensional and family resemblance sorts) with those carried out imperfectly (others, one-away unidimensional, and one-away family resemblance) between Experiments 2 and 3. The analysis revealed that preexposure improved participants' perceptual discrimination, $\chi^2(1, N = 14) = 4.1$, $p < .05$.[2] This result is in line with previous research that demonstrates preexposure can result in improved performance in a free classification task (e.g., Wills & McLaren, 1998), an effect that forms part of a

[2] Yates' correction for 2 × 2 chi-square tables has not been applied as results have shown that the conventional chi-square for 2 × 2 designs, without correction for continuity, is sufficient to prevent Type I errors (Overall, 1980). Added to this, the assumption of fixed marginals made by Yates' correction was not applicable for this data set. Howell (2002, pp. 151–152) offered an overview on the use of Yates' correction for 2 × 2 chi-squares.

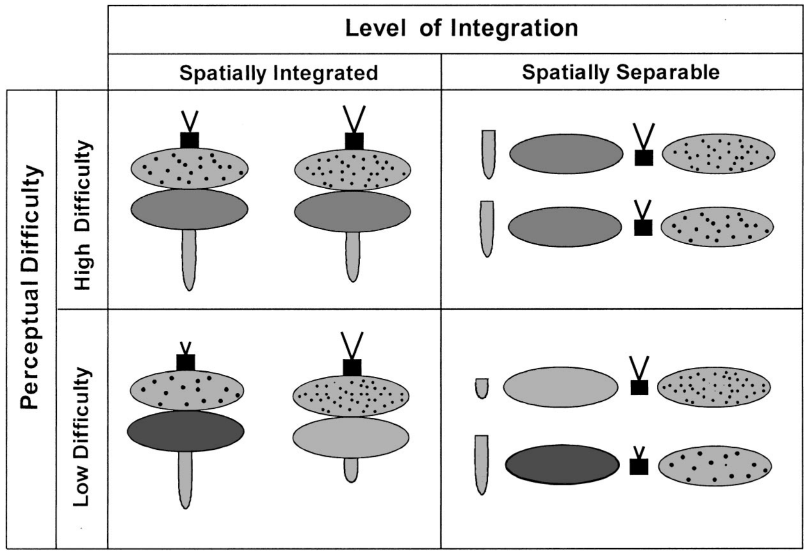

Figure 3. The prototypes for the four stimulus sets used in Experiment 4.

larger body of research on perceptual learning (e.g., Gibson & Walk, 1956; McLaren, 1997).

Nevertheless, the main finding of Experiment 3 is a confirmation that the match-to-standards procedure does not inevitably yield family resemblance sorts. This finding is all the more striking as the stimuli used here are arguably more similar to everyday objects than those used by Regehr and Brooks (1995). This suggests that the argument that an "unnatural" (unidimensional) sort is preferred because the stimuli are "unnatural" is hard to sustain. These studies also suggest that spatial integration does not necessarily encourage family resemblance sorting, as extrapolation of previous research (e.g., Garner, 1974; Handel & Imai, 1972) might suggest. Indeed, these studies have indicated that the opposite could be the case.

Experiment 4

It appeared that the difference in the results between Experiment 1 and Experiments 2 and 3 could be due to at least two factors: the spatial integration of the stimulus dimensions or the difference in perceptual difficulty. Experiment 4 was an investigation of the effects these two factors have on category construction.

Method

Participants. Forty-eight students from the University of Exeter participated either for course credits or were paid £2 (U.S. $3.64). None had participated in any of the previous experiments.

Stimuli. Four sets of stimuli were designed in which perceptual difficulty and spatial separateness could be manipulated in a relatively independent manner. All the sets of stimuli were based on the artificial butterflies used in Experiments 2 and 3, although they were modified to enable them to be separated more naturally. The four stimulus sets used were (a) perceptually difficult with high spatial integration, (b) perceptually difficult with low spatial integration, (c) perceptually simple with high spatial integration, and (d) perceptually simple with low spatial integration. Each stimulus had the same abstract structure as in the first three experiments (shown in Table 1). The prototypes of these four sets are shown in Figure 3.

Procedure. Experiment 4 used the same procedure as Experiment 3: Participants had first to match the pairs correctly and then sort the 10 stimuli in the set into two groups using the match-to-standards procedure. There were 12 participants in each of the four between-subjects conditions.

Results and Discussion

The results of Experiment 4 (shown in Table 3) once again demonstrate that the match-to-standards procedure does not inevitably produce family resemblance sort strategies. However, inspection of Table 3 indicates that there are differences between conditions. There was a significant overall effect of level of integration, $\chi^2(1, N = 48) = 7.605$, $p < .01$, revealing that participants in the low spatial integration condition produced a significantly greater number of family resemblance sorts than those in the high spatial integration condition. There was no overall effect of perceptual difficulty on the sort strategy, $\chi^2(1, N = 48) = 0.201$, $p > .5$. However, log-linear analysis[3] using the SYSTAT 9 (1998) statistical package revealed that there was a significant interaction between perceptual difficulty and level of integration (likelihood ratio = 5.203, $df = 1$, $p < .05$). Inspection of Table 3 indicates that this is due to the effect of spatial integration being significantly more pronounced at higher levels of perceptual difficulty. Because of the small sample sizes, particularly in the perceptually difficult/integrated condition, it was not possible to carry out a meaningful analysis on the preference for particular features in unidimensional sorts for the four stimulus sets in Experiment 4.

Experiment 4 provides further evidence that stimulus characteristics can influence the categories that we prefer to create in category construction experiments. The results are contrary to

[3] A general discussion of the use of log-linear analysis can be found in Howell (2002, pp. 655–690).

Table 3
Results of Experiment 4—Frequency of Sort Strategies for the Four Conditions Examining the Effect of Perceptual Difficulty and Level of Integration on Sort Strategy

	Sort strategy						
Condition	1-away UD	UD	Total UD	1-away FR	FR	Total FR	Other
Perceptually difficult/spatially integrated	1	11	12	0	0	0	0
Perceptually difficult/spatially separable	0	4	4	1	5	6	2
Perceptually simple/spatially integrated	1	8	9	1	2	3	0
Perceptually simple/spatially separable	0	7	7	1	4	5	0

Note. UD = unidimensional; FR = family resemblance.

what might be expected from previous research into the integral–separable distinction (e.g., Garner, 1974; Handel & Imai, 1972), which has shown that integral stimuli are more likely to evoke family resemblance sorting. The effect was therefore of some surprise to us, and we wanted to see whether it would generalize to a different stimulus set and larger sample size. The interaction between perceptual difficulty and spatial integration is also puzzling and worthy of further investigation.

Experiment 5

Experiment 5 was designed to test whether the surprising integration effect found in Experiment 4 and the integration–perceptual difficulty interaction generalizes to a different stimulus set.

Method

Participants. Seventy-two students from the University of Exeter participated either for course credits or for money. As before, none of the participants had participated in any of the previous experiments.

Stimuli. Similar to Experiment 4, there were four sets of stimuli in a 2 × 2 between-subjects factorial design examining the effect of perceptual difficulty and level of integration on category construction. The prototypical stimuli for the four sets are displayed in Figure 4. The stimuli were artificial lampshades that varied on four features: the number of dots on the lampshades (few dots/many dots), the width of the stem (thin/thick), the hue of the top part of the base (light gray/dark gray), and the length of the lower part of the base (long/short).

Procedure. Experiment 5 used the same procedure as Experiments 3 and 4. There were 18 participants in each of the four between-subjects conditions.

Results and Discussion

The results of Experiment 5 (shown in Table 4) again revealed an integration effect in which the spatially separable stimuli evoked more family resemblance sorts than the spatially integrated stimuli, $\chi^2(1, N = 72) = 8.236$, $p < .01$. There was, again, no significant effect of perceptual difficulty, $\chi^2(1, N = 72) = 2.788$, $p > .05$. However, a log-linear analysis similar to that carried out for Experiment 4 revealed that there was also no significant interaction between perceptual difficulty and level of integration (likelihood ratio = 1.246, $df = 1$, $p > .05$). Because of the small sample sizes in the spatially separate conditions, it was not possible to carry out a meaningful analysis on the preference for particular features in unidimensional sorts for the four stimulus sets in Experiment 5.

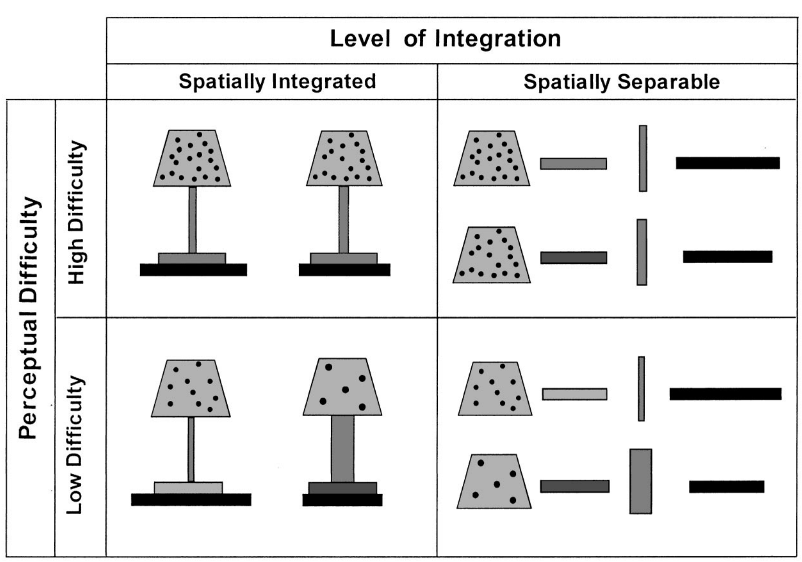

Figure 4. The prototypes for the four sets of stimuli used in Experiment 5.

Table 4
Results of Experiment 5—Frequency of Sort Strategies for the Four Conditions Examining the Effect of Perceptual Difficulty and Level of Integration on Sort Strategy

	Sort strategy						
Condition	1-away UD	UD	Total UD	1-away FR	FR	Total FR	Other
Perceptually difficult/spatially integrated	2	12	14	1	2	3	1
Perceptually difficult/spatially separable	2	4	6	1	10	11	1
Perceptually simple/spatially integrated	2	7	9	1	8	9	0
Perceptually simple/spatially separable	1	4	5	3	10	13	0

Note. UD = unidimensional; FR = family resemblance.

Experiment 5 confirms the results of the previous experiments by again demonstrating that stimuli with low spatial integration produce more family resemblance sorts than those with high spatial integration. It also demonstrates the match-to-standards procedure does not invariably produce family resemblance sorting. The puzzling interaction from Experiment 4 was not found to be robust to a change in stimulus type.

General Discussion

Previous research (e.g., Medin et al., 1987; Regehr & Brooks, 1995) indicates that people's preference for a unidimensional sort strategy in free classification is robust to substantial changes in stimulus procedures if an array procedure is used. The present series of experiments demonstrates that, in contrast, people's preference for a family resemblance strategy under a sequential match-to-standards procedure is quite sensitive to changes in stimulus type. In Experiment 1, in accordance with the findings of Regehr and Brooks, family resemblance sorting dominated when the stimuli were perceptually simple with dimensions of low spatial integration. However, for the stimuli used in Experiments 2 and 3, which were of greater perceptual difficulty and higher spatial integration, participants predominantly sorted unidimensionally.

Experiments 4 and 5 examined these two stimulus characteristics (perceptual difficulty and level of integration) factorially. Although low spatial integration increased the proportion of family resemblance sorts, the level of perceptual difficulty did not have a reliable impact. Perceptual difficulty interacted with spatial integration in Experiment 4, but we failed to replicate this result with the different stimuli used in Experiment 5. We are therefore disinclined to draw any firm conclusions from the significant interaction in Experiment 4.

Our results indicate that the match-to-standards procedure does not always produce family resemblance sorting. While acknowledging that none of our stimuli are as naturalistic as those found in, for instance, the work of Sloman, Harrison, and Malt (2002), it seems reasonable to argue that the stimuli used in Experiments 2 and 3 are closer to real-world objects than those used in most previous category construction experiments. Given this fact, our conclusion is of particular concern. One initially plausible explanation for the previous success of the match-to-standards procedure in evoking family resemblance sorts is that this procedure is more natural than the array procedure (on the grounds we seldom see all members of a category simultaneously). However, it would then also be expected that the more natural (in the sense of being closer to real-world objects) stimuli used in Experiments 2 and 3 should be categorized by family resemblance at least as frequently as the less natural (in the same sense) stimuli of Experiment 1. Instead, our stimuli in Experiment 2, which are modeled on a real-world object (a butterfly), resulted in fewer family resemblance sorts than the abstract stimuli of Experiment 1.

In other words, although this research echoes the findings of Regehr and Brooks (1995) that unidimensional sorting is not inevitably the dominant sort strategy in free classification, it would be wrong to suggest that it provides any great support for either a family resemblance theory of free classification or the appropriateness of the match-to-standards procedure to provide evidence for such a theory. One explanation often given for the dearth of family resemblance sorts in category construction experiments is that participants have no knowledge about the relationship between features, whereas most real-world objects have complex interproperty relationships (see Murphy & Medin, 1985, for a review). This theory has received some support from the work of Wattenmaker, Dewey, Murphy, and Medin (1986), who showed that background knowledge can facilitate the learning of linearly separable categories. Under certain conditions, background knowledge has also been shown to increase the quantity of family resemblance sorts in category construction experiments (Ahn, 1999; Spalding & Murphy, 1996). This suggests that a fuller understanding of the effect of background knowledge on category construction is potentially an area for future research.

Although ours is not the first demonstration of different types of stimuli being classified in different ways in unsupervised learning experiments (e.g., Handel & Imai, 1972), it is the first evidence that the stimulus characteristics influence the sort strategy under the category construction paradigm. Previous research has emphasized the procedure as the crucial factor in determining the sort strategy, with stimuli displayed in an array leading to unidimensional sorting (e.g., Medin et al., 1987) and stimuli presented with the match-to-standards procedure leading to a family resemblance sort (Regehr & Brooks, 1995). The present study, in contrast, underlines the impact different stimulus properties have on category construction.

Our initial attempts to characterize the specific stimulus properties that influence category construction (Experiments 4 and 5) produced a surprising yet robust result. The stimuli in Experiment 1 were spatially separate and produced predominantly family resemblance sorts, whereas the stimuli in Experiments 2 and 3 were spatially integrated and resulted virtually always in unidimensional sorts. This pattern continued into Experiments 4 and 5 when the perceptual difficulty of the stimuli, another potential explanation for the results, was controlled for. The spatially separable stimuli in both Experiments 4 and 5 produced significantly more family resemblance sorts than the spatially integrated stimuli.

This result is perhaps surprising when one considers previous research into free sorting of integral and separable stimuli. This research (cf. Handel & Imai, 1972; Kemler & Smith, 1979) has shown that integral stimuli (in which all the dimensions are perceived as a unitary whole) encourage sorting by overall similarity, whereas separable stimuli (in which the dimensions are perceived as being isolated) produce dimensional responding. It must be noted that none of the stimuli in this article are likely to be integral according to Garner's (1974) definition. Nevertheless, integrality–separability is often considered to be a continuum rather than a dichotomy (Foard & Kemler Nelson, 1984; L. B. Smith & Kemler, 1978), and therefore it would seem uncontroversial to suggest that spatially separate stimuli are more separable than are spatially integrated ones. Under these assumptions, it would be anticipated that the more spatially integrated stimuli would result in more family resemblance sorts than the spatially separable stimuli. In fact, the opposite occurred.

One possible explanation for this novel finding is that people who categorize by family resemblance are using an analytic as opposed to a nonanalytic strategy. In analytic processing, the attributes of stimuli are compared and used to generate hypotheses, whereas in nonanalytic processing the stimuli are categorized by overall similarity relations (Kemler Nelson, 1984).[4] It has commonly been thought that categorizing by family resemblance is a primitive process based on an overall similarity or nonanalytic approach. This view has been supported by developmental studies (Kemler Nelson, 1984; L. B. Smith & Kemler, 1977) that show that young children are more likely to categorize by overall similarity than on a dimensional basis. Individual differences have also been shown to influence sort strategy; for instance, Ward (1983) showed that people rated as impulsive (as opposed to reflective) on the matching familiar faces test produced more family resemblance sorts. It has also been argued that increased time pressure results in more family resemblance sorts (e.g., J. D. Smith & Kemler Nelson, 1984; Ward, Foley, & Cole, 1986).

Nevertheless, let us assume for a moment that all of our participants are using an analytic strategy to construct their categories. This appears to be a tenable assumption given that none of the experiments in this article have particularly similar task demands to the experiments just discussed. Let us further assume that the people who are categorizing by family resemblance are using a *dimensional summation* strategy as a basis for category construction (i.e., looking at each of the four dimensions individually and placing the stimulus into the category for which it has more characteristic features). In other words, the two strategies (unidimensional and family resemblance) are based on similar cognitive processes—those sorting by family resemblance are simply using a more sophisticated version of the dimensional strategy. It seems likely that separating out the dimensions in space makes them easier to differentiate. This is likely to make a dimensional summation strategy less effortful and quicker to apply to the easily separable stimuli than to the more integrated stimuli. Added to this, it is possible that simply separating out the stimuli may make participants more aware that they are ignoring relevant information, and this may also encourage them to use a summation strategy.

If this account is correct, it might be expected that perceptual difficulty would similarly influence family resemblance sorting. Although this manipulation was not significant in Experiments 4 and 5, it is possible that this was because the dimensions were not manipulated over a sufficiently wide set of values in these experiments. It is therefore plausible that an experiment in which each value is differentiated more strongly (e.g., red vs. blue wings, instead of light vs. dark blue) could produce a change in strategy similar to that found for the spatial integration variable.[5]

Another prediction derivable from our account is that preexposure, which has previously been shown to elicit perceptual learning in a free classification paradigm (e.g., Wills & McLaren, 1998), would similarly increase the differentiation between features and hence encourage family resemblance sorting. This approach is in contrast to previous category construction experiments in which participants have always had little or no preexposure. It seems possible that large amounts of preexposure could sensitize people to the correlation of features between categories. This would make it easier to build up a clearer idea of which features are usually associated with each other, perhaps making a family resemblance strategy easier to carry out. An investigation into the effects of preexposure on category construction is beyond the scope of this article, but it does appear to be a research area of some potential.

In summary, our investigation produced three main findings. First, the match-to-standards procedure introduced by Regehr and Brooks (1995) does not produce a universal preference for family resemblance sorts. As found in previous studies using an array procedure, and somewhat at odds with the idea that natural categories are family resemblance based, our participants showed high levels of unidimensional sorts in a match-to-standards procedure. Second, sort strategy was found to be highly sensitive to quite subtle changes in stimulus properties. This result contrasts with earlier findings that array sorting is relatively unaffected by large changes in stimulus types (Medin et al., 1987; Regehr & Brooks, 1995). Third, stimuli with spatially separate elements attracted more family resemblance sorts than stimuli in which the elements were placed adjacently to create a recognizable object. This result contrasts somewhat with previous findings that integral stimuli attract more family resemblance sorts than separable stimuli (Garner, 1974; Handel & Imai, 1972). From this, we argue that family resemblance sorting, at least in our experiments, is likely to be the result of analytic processing rather than the result of a perceptually driven, nonanalytic strategy (as family resemblance sorting has sometimes previously been characterized). Assuming this hypothesis is correct, a potential explanation of our spatial integration result is that the variation between features is easier to differentiate for stimuli with spatially separate elements, which facilitates the dimensional summation strategy we assume to underlie the family resemblance sorting we observe. Further predictions derivable from this account include that preexposure, which should (under certain conditions) facilitate differentiation between features, should thereby encourage family resemblance sorting. We also

[4] A general discussion of the analytic–nonanalytic distinction can be found in Brooks (1978).

[5] The ideas set out in this paragraph are due to Lee Brooks.

predict that, under our procedures and in contrast to previous findings (J. D. Smith & Kemler Nelson, 1984; Ward, 1983; Ward et al., 1986), increased time pressure should reduce the proportion of family resemblance sorts observed.

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