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13 Two Modes of Processing in Category Learning

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I. Introduction

Research has suggested that in category learning, it is more difficult to learn categories with more feature dimensions than ones with less feature dimensions (eg. Shepard, Hovland, & Jenkins, 1961). Difficulties in category learning among involving high numbers of feature dimensions has been attributed to a person having to divide their attention among more features. A study conducted by Hoffman & Murphy (2006) demonstrated the opposite phenomenon. Hoffman & Murphy (2006) compared performances of discriminating between two categories of imaginary creatures (bugs) in two conditions, a 4-dimension condition (4-D) and an 8-dimension condition (8-D). Despite the complexity of the figures, Hoffman and Murphy (2006) found that category learning was easier in the 8-D condition than in the 4-D condition.

Factors impacting category learning among an 8-D figures includes the use of non-verbal materials. The use of language can sometimes interfere with non-verbal cognitive processes. This interference is known as verbal overshadowing and has been observed in various non-verbal tasks, for example, face memory (Schooler & Engstler-Schooler, 1990; Fallshore & Schooler, 1995; Kitagami, Sato, & Yoshikawa, 2002; Ryan & Schooler, 1998), problem solving (Schooler, Ohlsson, & Brooks, 1993), decision making (Wilson, Lisle, Schooler, Hodges, Klaaren, & Lafleur, 1993). There are several explanations

on the causes of verbal overshadowing including attention shift (Schooler, 2002; Schooler, Fiore, & Brandimonte, 1997). In the attention shift explanation, it is suggested that two modes of processing are involved in non-verbal cognitive tasks; analytic and featural processing and non-analytic and holistic processing. Use of language causes attention to shift from non-analytic and holistic processing to analytic and featural processing, which is usually less appropriate for non-verbal tasks and hence, interferes with performances of non-verbal tasks. In Hoffman & Murphy's (2006) task, pictorial presentation might promote the non-analytic and holistic mode of processing which makes good use redundant features. We hypothesize that if verbal lists of features of the same imaginary creatures were used as learning materials, the analytic and featural mode of processing might be dominant and analyzing more redundant features could possibly deteriorate concept learning. Under these constraints it might be more difficult to learn 8-D categories than 4-D categories when the learning materials are presented in the form of verbal lists of features. It might also be easier to learn 8-D categories when the same pictures as Hoffman & Murphy's are used. This hypothesis was examined in the first experiment.

II. Experiment 1

1. Method

1.1. Participants

Forty-eight undergraduate and graduate students volunteered and participated individually.

1.2. Materials

For learning materials, the same pictures of the imaginary creatures as Hoffman & Murphy (2006) were used for the picture condition. Feature lists of Japanese descriptions of the creatures were used for the verbal-list condition. In both conditions, there were two categories of the creatures, mobbles and streaths, each of which had eight instances. Each instance had eight (8-D condition) or four (4-D condition) feature dimensions that varied between two values.

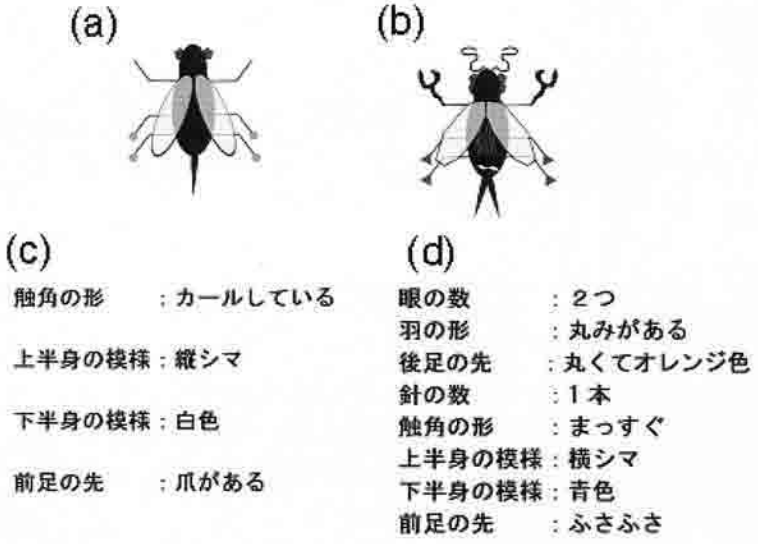

Figure 1. Samples of learning materials for (a) picture 4-D, (b) picture 8D, (c) verbal-list 4-D, and (d) verbal-list 8-D conditions.

Table 1. Structures of categories (from Hoffman & Murphy, 2006)

Items	8-D							
	$4\text{-}D_1$				$4\text{-}D_2$			
	D1	D2	D3	D4	D5	D6	D7	D8
	Mobbles							
1	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	1	0
3	0	0	0	0	0	1	0	0
4	0	0	0	0	1	0	0	0
5	0	0	0	1	0	0	0	0
6	0	0	1	0	0	0	0	0
7	0	1	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0
	Streaths							
1	1	1	1	1	1	1	1	0
2	1	1	1	1	1	1	0	1
3	1	1	1	1	1	0	1	1
4	1	1	1	1	0	1	1	1
5	1	1	1	0	1	1	1	1
6	1	1	0	1	1	1	1	1
7	1	0	1	1	1	1	1	1
8	0	1	1	1	1	1	1	1

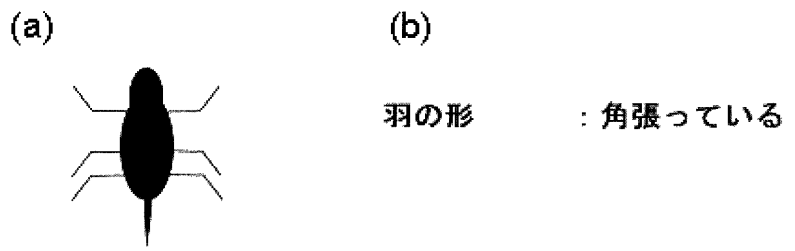

Figure 2. Samples of single-feature test items for (a) picture condition and (b) verbal-list condition.

Each category had a family resemblance structure and looking at any sets of three dimensions was necessary and adequate to discriminate the categories. Samples of the instances are shown in Figure 1. The structures of categories are shown in Table 1.

Test materials were also prepared in pictorial or verbal form. Each test item had only one feature. There were 16 test materials for picture condition and verbal-list condition. Samples of the test stimuli were shown in Figure 2.

1.3. Procedure

Procedures were almost identical to those used by Hoffman & Murphy (2006, Experiment 3) with the exception of the verbal-list condition.

Learning phase: Participants were randomly assigned to one of the presentation formats (picture or verbal-list) x feature dimension (8-D or 4-D) conditions. In one block, sixteen instances (eight from mobbles and eight from streaths) were randomly presented on a computer screen one by one. Participants were required to judge whether the item was a mobble or a streath and respond with "z" key or "/" key that were assigned to mobbles and streaths. After the response, the item stayed on the screen with a response correctness feedback for 4 seconds, and then after one second blackout, the next item was presented. The learning blocks were repeated eight times or until the participant responded correctly to all 16 stimuli in a block.

Test phase: Immediately after the learning phase, the test phase was conducted. Sixteen learning materials and test materials were presented twice randomly. Participants were required to judge which category the presented item related strongly to and respond with the same keys as in the learning

Table 2. Numbers of participants who reached the learning criterion and median blocks when the learning criterion was reached (Experiment 1)

Presentation format	Category structure			
	4-D		8-D	
	N of participant	Median	N of participant	Median
Picture	9	7	11	5
Verbal-list	11	3	10	3

phase.

2. Results

2.1. Learning phase

The numbers of the participants who reached the learning criterion and the medians of numbers of the blocks when the learning criterion was reached are provided in Table 2. Proportions of correct responses were calculated putting one for the blocks after the learning criterion was reached. Figure 3 shows the mean proportion correct for each block for each presentation format and number of dimensions. These results seem to show that learning was difficult in the picture 4-D condition.

It may be reasonable to think that the effect of the learning conditions was not prominent in the first few blocks. A two (presentation formats) by two (feature dimensions) by four (blocks) analysis of variance (ANOVA) was conducted on the rates of correct responses of the last half of the learning blocks. A marginally significant main effect was found for presentation format (.95 and .98 for picture and verbal-list conditions, respectively, $F(1, 44)=3.94$, $p=.05$) and a significant interaction between presentation format and feature dimensions was found ($F(1,44)=5.99$, $P<.05$). The tests of simple main effects indicated that performance for the 8-D condition (.98) was higher than the one for the 4-D condition (.92) when the learning materials were presented in the pictorial format. On the other hand, there were no significant simple main effects for feature dimensions when the materials were presented verbally (.99 and .97 for 4-D and 8-D conditions). The main effect of block and the

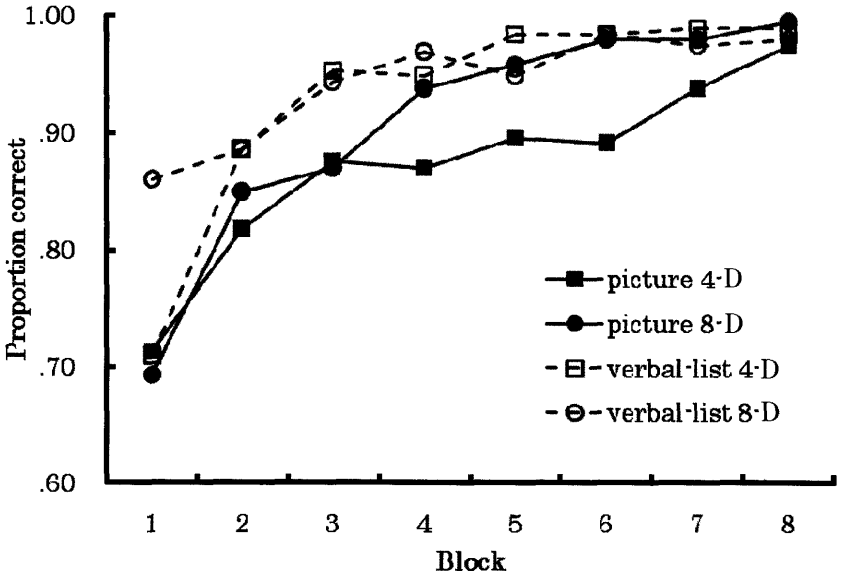

Figure 3. Proportion correct for each condition in learning phase (Experiment 1).

interaction of presentation format and block were also significant.

Table 3 shows the mean reaction time (RT) for the first two learning blocks for each condition. We analyzed RTs for the first two blocks because some of the participants reached the learning criterion in the second block. A two (presentation formats) by two (feature dimensions) by two (blocks) ANOVA found all three main effects to significant. Mean RT was longer for the verbal-list condition compared to the picture condition ($F(1,44)=25.75$, $p<.001$), for the 8-D condition compared to the 4-D condition ($F(1,44)=5.14$, $p<.05$) and for the first block compared to the second block ($F(1,44)=44.25$, $p<.001$). Interactions between presentation format and block ($F(1,44)=46.10$, $p<.001$) and between dimension and block ($F(1,44)=5.33$, $p<.05$) were significant. An interaction between presentation format and dimension was marginally significant ($F(1,44)=3.22$, $p<.1$). Finally, an interaction among three factors was also significant ($F(1,44)=7.51$, $p<.01$). Further analyses showed that there was a simple interaction between presentation formats and dimension for the first block ($F(1,88)=7.43$, $p<.01$), where the mean RT was longer for the 8-D condition than the 4-D condition only for the verbal-list condition ($F(1,88)=16.34$, $p<.001$). No significant differences between RTs for the 4-

Table 3. Reaction times for the first two blocks of the learning trials (s) (Experiment 1)

Block	Picture			Verbal-list			Ave.		
	4-D	8-D	Ave.	4-D	8-D	Ave.	4-D	8-D	Ave.
1st	1.74	1.87	1.80	4.00	6.81	5.41	2.87	4.34	3.60
2nd	1.68	1.98	1.83	2.38	3.24	2.81	2.03	2.61	2.32
Ave.	1.71	1.92	1.81	3.19	5.03	4.11	2.45	3.47	2.96

Table 4. Proportions correct for whole and single-feature items in the test phase and numbers of dimensions learned (Experiment 1)

Presentation	Whole items		Single-feature items		Dim learned	
format	4-D	8-D	4-D	8-D	4-D	8-D
Pcture	.92	.93	.92	.68	3.3	3.1
Verbal-list	.98	.95	.96	.82	3.7	5.2

D and 8-D conditions were detected for the picture condition or for the second block of the verbal-list condition. In picture condition, participants in the 4-D and 8-D conditions spent same amount of time and learning proceeded faster for the 8-D condition than the 4-D condition. In the verbal-list condition, 8-D participants spent more time than 4-D participants, especially in the first learning block, and learning proceeded at the similar rate in both 4-D and 8-D conditions.

2.2. Test phase

There were two kinds of test materials, ones presented in the learning phase (whole items, hereafter) and ones with only one feature (single-feature items). Table 3 shows proportions of correct responses for the whole items and the single-feature items. The estimated numbers of dimensions that were learned by the participants are also provided in Table 4. These were calculated to compare the result for the 4-D and the 8-D conditions by the same formula to Hoffman & Murphy's (2006), that is, $D_{learned} = D_{total}(P_{correct} - P_{incorrect})$, where D_{total} was the total number of the dimensions (i.e. four or eight), $P_{correct}$ was proportion correct, $P_{incorrect}$ was proportion incorrect for single-feature items.

Two (presentation formats) by two (feature dimensions) ANOVAs were applied to these data. Only a main effect for presentation format was detected for proportion correct for whole items ($F(1,44)=4.47$, $p<.05$). The proportion was higher for the verbal-list condition (.97) than the picture condition (.92). For the proportion correct for single-feature items, main effects of presentation format and dimension were significant ($F(1,44)=11.21$, $p<.005$, for presentation format; $F(1,44)=45.47$, $p<.001$, for dimension). An interaction was marginally significant ($F(1,44)=3.38$, $p<.1$), indicating that the difference between feature dimensions were larger for the picture condition. For the estimated number of dimensions learned, a main effect of presentation format ($F(1,44)=9.23$, $p<.005$) and an interaction ($F1,44)=7.16$, $p<.05$) were significant. In the verbal-list condition, significantly more dimensions were learned in the 8-D condition than in the 4-D condition. In the 8-D condition, significantly more dimensions were learned in the verbal-list condition than in the picture condition. Other simple main effects were not significant.

3. Discussion

The picture condition was identical to Experiment 3 of Hoffman and Murphy (2006). Similar to Hoffman & Murphy (2006), results of the learning phase found that participants in the 8-D condition learned category discrimination faster than participants in the 4-D condition. Performance of the last half of the learning phase was higher for the 8-D condition than the 4-D condition. More participants reached the learning criterion in the 8-D condition than the 4-D condition. In addition, for the whole items, the proportions correct for both 4-D and 8-D conditions were high and there was no difference between them in picture condition.

However, in contrast to Hoffman & Murphy's experiment, the single-feature items did not demonstrate a difference in the estimated numbers of dimensions learned in this experiment. In Hoffman & Murphy, 8-D participants learned more dimensions (4.5) than 4-D participants (2.9). In this experiment, 8-D participants learned numerically less dimensions then 4-D participants.

We first hypothesized that learning would be more difficult in the verbal-list condition in the 8-D condition than the 4-D condition due to divided attention. Results for the verbal-list condition did not support our hypothesis. Learning in the 8-D condition was as fast as learning in the 4-D condition. In

the last half of the learning phase, in the verbal-list 4-D condition, rate of correct responses were as high as the rates in the picture 8-D condition and higher than ones in the picture 4-D condition. Rates of correct responses in the whole-item test were very high and there were no differences between the 4-D and 8-D conditions. These results were also inconsistent with verbal overshadowing effect that is observed in lots of non-verbal cognitive tasks.

A possible factor to explain the results is reaction time. Participants could spend as long as they liked before they made a response in a learning trial because reaction times were not restricted in this experiment. Actually, analysis of reaction times for the first two learning blocks shows that participants in verbal-list condition spent more than twice as long as ones in picture condition. Especially, participants in the verbal-list 8-D condition spent much longer than ones in any other conditions in the first block. Taking long time in the first several learning blocks might have compensated the disadvantage of the verbal-list 8-D condition.

Results of this experiment suggested that categories with more feature dimensions are easier to learn when they are presented in pictorial format relying on non-analytic and holistic processing compared to verbal presentation which relies on analytic and featurral processing. Although rates of correct responses in the learning phase and of the whole-item test were higher for the verbal-list condition than the picture condition, it is not clear whether verbal, analytical and featural processing is advantageous in such category learning because participants spent more time in the verbal-list condition than in the picture condition.

III. Experiment 2

In the learning phase of Experiment 1, participants could respond whenever they wanted after an item was presented in a trial. This caused the differences in the amount of time spent during a learning block among conditions. To address this issue, in Experiment 2, we fixed the duration interval in which each learning item was presented on the computer screen. In Experiment 1, a learning item was presented until participants made a response and then four more seconds with a feedback of correctness of the response. In Experiment 2, an item was presented for ten seconds regardless of the participant's response.

In this experiment, it was hypothesized that the advantage of verbal-list condition that was observed in Experiment 1 would decrease or disappear and that 4-D category learning would also be easier than 8-D category learning. In the picture condition, it was not clear whether the advantage of 8-D categories would disappear or not because it is conceived that feature dimensions are not processed one by one in non-analytical and holistic processing.

1. Method

1.1. Participants

Forty-eight undergraduate and graduate students who had not participated in Experiment 1 volunteered and participated individually.

1.2. Materials

Both learning and test materials were the same as those used in Experiment 1.

1.3. Procedure

The procedure was almost identical to Experiment 1 except the modification in the durations of learning items and feedback timing. Participants were instructed to respond within six seconds after a learning item was presented. On a trial in which a participant made a response within six seconds from the onset of the learning item, the item remained presented for ten seconds with a correct/wrong feedback added when she/he made a response. If a participant did not respond in six seconds, a display "time-out" and a correct answer were presented with the learning item for four seconds. Each learning item was presented for ten seconds regardless of the participant's response in each trial.

2. Results

2.1. Learning phase

Table 5 shows the numbers of the participants who reached the learning criterion and the medians of numbers of the blocks when the learning criterion

was reached. Figure 4 shows the mean proportion correct. A two (presentation formats) by two (feature dimensions) by four (blocks) ANOVA was applied to the rates of correct responses of the last half of the learning blocks. Significant main effects of category structure ($F(1,44)=5.05$, $p<.05$) and block ($F(1,44)=5.447$, $p<.005$) were detected. An interaction between presentation format and category structure was also significant ($F(1,44)=7.54$, $P<.01$). The tests of simple main effects revealed that the performance for the picture 8-D condition (.93) was significantly lower than the picture 4-D condition (1.00,

Table 5. Numbers of participants who reached the learning criterion and median blocks when the learning criterion was reached (Experiment 2)

Presentation format	Category structure			
	4-D		8-D	
	N of participant	Median	N of participant	Median
Picture	12	4.5	7	6.5
Verbal-list	11	4.5	12	4.5

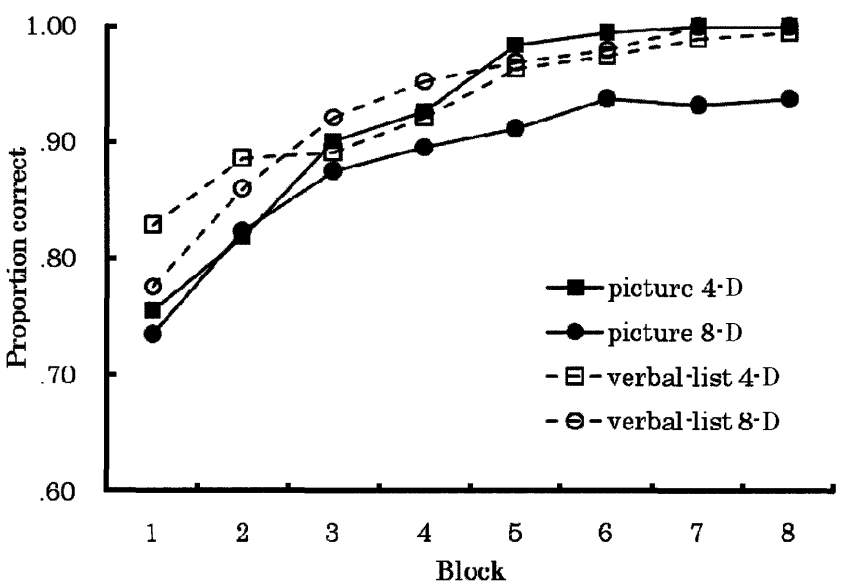

Figure 4. Proportion correct for each condition in learning phase (Experiment 2).

Table 6. Proportions correct for whole and single-feature items in the test phase and numbers of dimensions learned (Experiment 2).

Presentation	Whole items		Single-feature items		Dim learned	
format	4-D	8-D	4-D	8-D	4-D	8-D
Pcture	.97	.94	.86	.77	2.9	4.3
Verbal-list	.96	.95	.97	.78	3.8	4.5

F(1.44)= 12.45, p<.001) and the verbal-list 8-D condition (.98, F(44,1)= 9.66, p<.005). There were no differences between the picture 4-D and the verbal-list 4-D conditions or between the verbal-list 4-D and the verbal-list 8-D conditions.

In Experiment 2, time spent in learning blocks seemed to have accelerated learning in the picture 4-D condition to the similar level of the verbal-list conditions. However, performance of the picture 8-D condition seemed to have dropped. Inconsistent to proposed hypotheses, learning did not proceed faster in the 4-D condition than the 8-D condition in the verbal-list condition.

2.2. Test phase

Table 6 shows the proportions of correct responses for the whole items and the single-feature items. The estimated numbers of dimensions learned by the participants were calculated as in Experiment 1 are provided in Table 6. Two (presentation formats) by two (dimensions) ANOVAs were conducted on the data. No main effects or interaction was significant for proportion correct for whole items. Learning advantages of the verbal-list condition observed in Experiment 1 disappeared and disadvantage of the picture 8-D condition was not detected. For the proportion correct for single-feature items, a main effect of dimension was significant (F(1,44)=17.04, p<.001). A main effect of presentation format was marginally significant (F(1,44)=3.68, p<.01). For the estimated numbers of dimensions learned, only a main effect of dimension (F(1,44)=6.89, p<.05) was significant. More dimensions were learned in the 8-D condition than in the 4-D condition for both the verbal-list condition and the picture condition.

3. Discussion

Contrary to Experiment 1 and the results of Hoffman and Murphy (2006), learning occurred faster in the 4-D than the 8-D condition when learning materials were presented in pictorial format. This tendency might be predicted in conditions where feature dimensions can be processed one by one and attention resources are divided to the dimensions. In Experiment 2, participants had much more time to learn each item which may have led to the dominance of analytical and featural processing.

In the verbal-list condition, learning in the 8-D condition occured at the same rate as the 4-D condition. We expected that controlling the amount of learning time to the same level might produce an advantage in the 4-D condition. Consequently, the results may reflect a ceiling effect in both 4-d and 8-d conditions. We set the duration intervals of learning items to the same level as the average latency in the first block of verbal-list 8-D condition in Experiment 1. This means that participants in verbal-list 8-D condition had enough time to fully analyze the features of the learning items and learn them. A possible reason to explain why learning in the picture 8-D condition was slower than the other conditions might be that complicated categories were more difficult to analyze when category items were presented in pictorial format.

Performance in the whole-item test was lower in the 8-D than the 4-D condition in picture condition although the difference was not significant. Nevertheless, the number of dimensions learned was higher for 8-D than 4-D condition. In Experiment 1, there was no such difference. We will address this discrepancy in the general discussion.

IV. General Discussion

We hypothesized that two kinds of processing were involved in category learning: analytic and featural processing and non-analytic and holistic processing. In conditions where analytic and featural processing were dominant, redundant dimensions deteriorated learning because attention resources were distributed among dimensions rather than focused on specific dimensions. Whereas in conditions where non-analytic and holistic processing were

dominant, redundant dimensions might not deteriorate learning or possibly improve learning because the redundant dimensions can serve as discrimination cues without suffering decline in learning of each dimension. In Experiment 1, we hypothesized that it would be more difficult to learn categories with more redundant dimensions when learning materials were presented in verbal format leading to analytic and featural processing dominance. On the other hand, categories with more redundant dimensions would not be so difficult, or they would be even easier to learn when materials were presented in pictorial format leading to non-analytic and holistic processing dominance.

As expected, participants learned category discrimination faster when the categories had more dimensions in the picture condition. In the verbal-list condition, no difference was observed in performances in the learning phase or in the whole item test in the test phase. As a whole, performance in the verbal-list condition was somewhat better than in the picture condition.

Differences in reaction times in the learning phase explained the unexpected data for the verbal-list condition. Participants in the verbal-list 8-D condition spent more time than one in the verbal-list 4-D condition, who spent more time than the picture 4-D and 8-D conditions. Participants in the verbal-list condition might have time as a factor to analyze the dimensions.

In Experiment 2, we set item presentation durations in the learning phase equal to all the conditions. By doing so, we expected that disadvantage of the 8-D condition was observed in the verbal-list condition while the advantage of the 8-D condition remained in the picture condition. However, performances in both of the verbal-list 4-D and 8-D conditions were very high and there was no difference between them. This may be explained in terms of a ceiling effect because participants had more learning time in verbal-list 8-D condition in Experiment 1 where they spent as much time as they wanted and performed very well.

On the other hand, results for the picture condition were unexpected and difficult to explain. In the picture condition, performances were better for the 4-D condition than the 8-D condition. If non-analytic and holistic processing is dominant in these conditions, performance in the 8-D condition should be as high as in the 4-D condition, or higher as in Experiment 1. A possible explanation for this finding could be that having too much time caused dominance of analytic and featural processing in the picture condition. In the picture 4-D condition, materials were simple enough for analytic and featural

processing to cope with. However, in the picture 8-D condition, materials were too complicated to analyze and to learn. Actually, one would have to decompose each item into features and this task is not required in the verbal-list condition.

A set of data might support this explanation. In Experiment 1, the estimated numbers of dimensions learned by picture condition participants were about three, which is the minimum to discriminate the categories. However, in Experiment 2, participants in the picture 8-D condition learned more than four dimensions although their performance in learning phase was poor. Having learned more dimensions seems to be characteristic to analytic and featural processing from theoretical and experiential points of view. That is, it must be difficult to respond correctly to isolated features even if the categories are learned non-analytically and holistically. In both experiments in this study, the verbal-list condition participants learned more dimensions.

In this study, it was suggested that there was a learning advantage among categories with more redundant dimensions was observed only when non-analytic and holistic processing was dominant and a learning disadvantage was observed under some conditions where analytic and featural processing was dominant. Experiments in which differences in processing modes can be seen more directly and in which processing modes are manipulated more directly are strongly encouraged for future studies.

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Appendix

English translations of Fig. 1 (c), (d), and Fig. 2 (b).

Fig. 1 (c)
shape of the antennas: curled
pattern on the upper body: vertical stripes
markings on the lower body: white
toes of the fore legs: with claws

Fig. 1 (d)
number of eyes: two
shape of the wings: round
toes of the hind legs: orange circles
number of tails: one
shape of the antennas: straight
pattern on the upper body: horizontal stripes
markings of the lower body: blue
toes of the fore legs: brushy

Fig. 2 (b)
shape of the wings: angulate