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Effects of stimulus duration and choice delay on visual categorization in pigeons

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Abstract

We (Lazareva, Freiburger, & Wasserman, 2004) previously trained four pigeons to classify color photographs into their basic-level categories (cars, chairs, flowers, or people) or into their superordinate-level categories (natural or artificial). Here, we found that brief stimulus durations had the most detrimental effect on the basic-level discrimination of natural stimuli by the same pigeons. Increasing the delay between stimulus presentation and choice responding had greater detrimental effect on the basic-level discrimination than the superordinate-level discrimination. These results suggest that basic-level discriminations required longer stimulus durations and were more subject to forgetting than were superordinate-level discriminations. Additionally, categorization of natural stimuli required longer stimulus durations than categorization of artificial stimuli, but only at the basic level. Together, these findings suggest that basic-level categorization may not always be superior to superordinate-level categorization and provide additional evidence of a dissociation between natural and artificial stimuli in pigeons' categorization.

Keywords

visual categorization; stimulus similarity; forgetting; basic-level categorization; superordinate-level categorization; pigeons

Object recognition in humans often involves categorization at what are considered to be different levels of abstraction. For example, an object may be classified as a Porsche (subordinate level), a car (basic level), or a vehicle (superordinate level). Categorization at the basic level is generally believed to be encouraged by high within-category perceptual similarity and by low between-category perceptual similarity (Rosch & Mervis, 1975). Categorization at the superordinate level involves the aggregation of basic-level categories into higher-level groupings, whereas categorization at the subordinate level is based on subgroups within basic-level categories. Consequently, superordinate categorization entails low between- and within-category similarity, whereas subordinate categorization entails high between- and within-category similarity, rendering these two levels of categorization less preferred than the basic level (Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976).

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Beginning with a series of highly influential studies by Rosch and her colleagues (Mervis & Rosch, 1981; Rosch & Mervis, 1975; Rosch et al., 1976), the basic level has been found to enjoy a number of advantages in a variety of cognitive tasks. First, in the course of development, children tend to acquire basic-level categories before they acquire superordinate-level categories (Horton & Markman, 1980; Markman & Hutchinson, 1984; Mervis & Crisafi, 1982; Rosch et al., 1976; but see Behl-Chadla, 1996; Mandler & McDonough, 2000; Mareschal & Quinn, 2001). Second, people appear to prefer to use basic-level terms (e.g., “dog”) to name pictures of objects rather than superordinate-level terms (e.g., “animal”) or subordinate-level terms (e.g., “German Shepherd”; Lin, Murphy, & Shober, 1997; Rosch et al., 1976). Third, people are faster to name a picture of an object at the basic level than at either the superordinate or the subordinate level (Jolicoeur, Gluck, & Kosslyn, 1984; Murphy & Brownell, 1985; Murphy & Smith, 1982; Rosch et al., 1976). Finally, when presented with a category name followed by a picture of an object and asked to confirm whether they match, people are faster to verify basic-level categories than to verify superordinate-level or subordinate-level categories (Jolicoeur et al., 1984; Murphy & Smith, 1982; Rosch et al., 1976). Although extensive expertise in a given domain may reduce the disparity between the basic level and the subordinate level (Tanaka & Taylor, 1991), the basic level has consistently been found to be superior to the superordinate level.

Many researchers have reported that birds and nonhuman primates can categorize natural objects, such as people or trees (D’Amato & Van Sant, 1988; Herrnstein & Loveland, 1964; Poole & Lander, 1971; Roberts & Mazmanian, 1988; Sands, Lincoln, & Wright, 1982; Schrier & Brady, 1987; Tanaka, 2001; Vogels, 1999; Vonk & McDonald, 2004), as well as artificial objects, such as cars or chairs (Lubow, 1974; Wasserman, Kiedinger, & Bhatt, 1988). Several other researchers have also documented nonhuman animals’ ability to learn superordinate discriminations either as a separate task (Roberts & Mazmanian, 1988; Vonk & McDonald, 2002; Vonk & McDonald, 2004; Wasserman, DeVolder, & Coppage, 1992) or to do so concurrently with a basic-level discrimination task (Lazareva, Freiburger, & Wasserman, 2004).

Most prior research on superordinate categorization in animals has involved associating a human-language superordinate-level category (e.g., animals) with common response such as a choice of a specific response or a common outcome such as a reinforcer. Only a few studies have explicitly explored to what extent the resulting classes of stimuli resemble human-language superordinate-level categories. Wasserman et al. (1992) showed that pigeons trained to associate perceptually diverse stimuli (e.g., cars and chairs) with the same response integrate them into a single class of functionally equivalent stimuli. When after such training a subset of the stimuli was associated with a novel response, a procedure called reassignment (Lea, 1984), pigeons transferred this new response to the untrained stimuli. Although Lea (1984) proposed that the reassignment test is the only appropriate test of the categorical nature of stimulus classes, later research has revealed surprising failures to obtain reassignment even when the categorical coherence of the stimuli was clearly established by alternative methods (Nagasaka & Wasserman, 2006). Here, we tentatively assume that our higher-level categories of natural and artificial stimuli are functionally equivalent to human-language superordinate-level categories, based on prior data obtained by Wasserman et al. (1992). However, we use the terms *natural* and *artificial* simply as convenient labels for two groups of stimuli. These terms do not imply that the pigeons actually learn the concept of *natural* versus *artificial* or that they would generalize their discriminative responses to different basic-level categories belonging to these superordinate-level categories.

Recently, we (Lazareva et al., 2004) trained pigeons to concurrently discriminate color photographs of cars, chairs, flowers, and people at either the basic level or the superordinate level (natural: flowers and people, or artificial: cars and chairs). Figure 1 portrays a sample of

the training stimuli. During a training session, each photograph randomly required categorization at the basic or the superordinate level. For example, if a photograph of a flower was shown along with four choice keys, then the pigeon had to select the key that was associated with the proper basic-level category (all flower images). If the same photograph was shown along with two different choice keys, then the pigeon had to select the key that was associated with the proper superordinate-level category (natural: all flower and human images). This approach afforded us an opportunity to evaluate concurrent categorization at the basic level and at the superordinate level using both natural and artificial stimuli.

Figure 2 illustrates the results of the original discrimination training that we reported earlier (Lazareva et al., 2004). Overall (Figure 2, top panel), pigeons were faster to learn the basic-level task than the superordinate-level task.¹ Surprisingly, detailed analysis revealed dramatic disparities among the natural and artificial stimuli (Figure 2, bottom panel). Only the artificial stimuli (cars and chairs) were discriminated significantly more readily at the basic level than at the superordinate level. The natural stimuli (flowers and humans) were more readily discriminated at the superordinate level than at the basic level, although the disparity was not statistically significant.

Why did we find the basic-before-superordinate trend for artificial stimuli and the superordinate-before-basic trend for natural stimuli? The confusion errors that we collected in the basic-level discrimination task suggested that photographs of flowers and people were prone to be confused with each other (47.0% of errors compared to 33.3% expected by chance), whereas photographs of cars and chairs were not (30.5% of errors). This result suggests that the relatively dissimilar exemplars of artificial categories may be easy to distinguish at the basic level, but they may be hard to group at the superordinate level, whereas the relatively similar exemplars of natural categories may be easy to group at the superordinate level, but be difficult to distinguish at the basic level. Despite these intriguing findings, further research is clearly necessary to corroborate this promising proposal.

In the present experiment, we explored effects of two temporal variables, stimulus duration and choice response delay, on pigeons' categorization of natural and artificial stimuli at two different levels, basic and superordinate. Both of these variables require pigeons to perform the choice response in absence of the pictorial stimulus (see Figure 3) and therefore introduce memory demands. Normally, the failure to respond correctly in absence of the stimulus would be deemed to occur because of failure to encode initial information, failure to retrieve the already encoded information, or both. Suppose that the organism's task is to discriminate two classes of stimuli at a given stimulus duration. If the organism's ability to correctly discriminate one class of stimuli was lower than its ability to correctly discriminate a different class of stimuli, then we would conclude that the evidence suggests differential encoding of these two stimulus classes. However, differential encoding implies that the nature of the task is known in advance. In our experiment, both basic-level trials and superordinate-level trials look the same until the presentation of the choice keys; therefore, we should not expect any differential encoding to occur before the choice keys are given.

It is possible however, that initial discriminability of the basic-level categories would affect pigeons' performance. Similar basic-level categories would necessitate the extraction of more detailed information; therefore, longer stimulus durations would be required for successful discrimination than would dissimilar basic-level categories. Consequently, we would expect that, as stimulus duration decreases, accuracy to natural basic-level categories would decrease faster than accuracy to artificial basic-level categories.

¹To make the basic-level (25% chance level) and superordinate-level discriminations (50% chance level) directly comparable, we transformed the percentage of correct choices to the signal detection measure d' (see more details in Method section).

Manipulating choice response delay offers an opportunity to explore differences in both initial discriminability and forgetting of the stimuli (White, 2001). Initial discriminability of the stimuli is reflected in accuracy at a 0-s delay when no memory demands are present. Here, we expected higher accuracy at a 0-s delay for artificial basic-level categories than for natural basic-level categories. Stimulus forgetting is reflected in the rate of decline of discrimination accuracy with an increase in delay of the choice response. Again, similar basic-level categories should require more details at the time of retrieval for accurate discrimination than should dissimilar basic-level categories. Therefore, as the choice response delay increases, discrimination accuracy to natural basic-level categories ought to decline faster than to artificial basic-level categories. Finally, we expect superordinate-level discrimination to be more accurate than basic-level discrimination in both cases, as superordinate-level discrimination ought to require less detailed representations than basic-level discrimination.

Method

Subjects

Four feral pigeons (*Columba livia*) were maintained at 85% of their free-feeding body weights by controlled daily feeding. The birds were previously trained to concurrently categorize photographs at the basic and superordinate levels using a four-button forced-choice procedure (Lazareva et al., 2004; Lazareva, Freiburger, & Wasserman, 2006).

Stimuli

The 64 discriminative stimuli were photographs from the World Wide Web plus digital photographs taken by the second author and used in our prior studies (Lazareva et al., 2004; Lazareva et al., 2006). The original background of each photograph was replaced by a solid 20% gray shading using Photoshop® 7.0 (Adobe®, San Jose, CA) and KnockOut 2 (Procreate™, Ottawa, Canada). The stimuli came from four basic-level categories: cars, chairs, flowers, and people. We created eight subsets of photographs composed of two stimuli in each category that were primarily black, blue, green, orange, pink, purple, red, or yellow. Small areas of other colors (such as the tires of cars, the faces of people, and the legs of chairs) were allowed as well. All of the target objects had approximately the same area and were presented in different orientations which were counterbalanced across images. The 64 images were divided into two sets (1 and 2) of 32 whose colors were balanced across black, blue, green, orange, pink, purple, red, or yellow. Examples of the stimuli can be seen in Figure 1; the complete collection of training and testing stimuli can be seen in color at <http://www.psychology.uiowa.edu/staff/olga/catStimuli.html>.

Apparatus

The experiment used four 36 × 36 × 41 cm operant conditioning chambers detailed by Gibson, Wasserman, Frei, and Miller (2004). The boxes were located in a dark room with continuous white noise. The stimuli were presented on a 15-in LCD monitor located behind an AccuTouch® resistive touchscreen (Elo TouchSystems, Fremont, CA). A food cup was centered on the rear wall level with the floor. A food dispenser delivered 45-mg food pellets through a vinyl tube into the cup. A houselight on the rear wall provided illumination during the session. Each chamber was controlled by an Apple® iMac® computer. The experimental procedure was programmed in HyperCard (Version 2.4, Apple Computer, Inc., Cupertino, CA).

One 10.16-cm square, or button, in the middle of the screen was used to display the photographs and to record observing responses; the rest of the screen was black. Six black Macintosh icons on white backgrounds served as the report buttons and were 3.30 cm wide × 2.79 cm high. The basic-level report buttons were placed at the corners of the square center button. For two birds,

the superordinate-level buttons were above and below the central display; for the other two birds, the superordinate-level buttons were left and right of the central display (see Figure 3).

Procedure

Prior to the two temporal manipulations, all of the birds were re-trained to perform the concurrent within-session simultaneous discriminations at the basic-level (four-alternative forced-choice report) and the superordinate level (two-alternative forced-choice report) for at least 8 consecutive training sessions. At that time, the birds were slightly more accurate in the basic-level task ($d' = 2.77 \pm 0.11$) than in the superordinate-level task ($d' = 2.72 \pm 0.12$), but this disparity was not statistically significant. Similarly, the birds were slightly better on average discriminating the artificial stimuli ($d' = 2.78 \pm 0.11$) than the natural stimuli ($d' = 2.71 \pm 0.11$), but this disparity was not statistically significant.

Stimulus Duration Training—First, pigeons were trained to categorize the stimuli when they were presented for a fixed duration of 10 s. Figure 3 (right panel) illustrates the sequence of events in the course of a superordinate-level stimulus duration trial. A trial began when the pigeon was shown a black cross in the center of the white display screen. Following one peck anywhere on the display, a training photograph appeared for a fixed interval of 10 s. After 10 s elapsed, the bird had to peck the stimulus once; this procedure ensured that the pigeon was attending to the stimulus at the end of the scheduled duration. After that, the training image disappeared and the report buttons appeared, so that the pigeons had to perform the choice in the absence of the training image. Basic and superordinate trials were randomly presented throughout a session. In duration training, the ITI ranged from 6 to 18 s for different birds. The ITI was adjusted depending on performance of each bird. If the bird failed to reach criterion in a timely manner, then the ITI was raised. Conversely, if the bird failed to complete a session due to a high ITI requirement, then the ITI was decreased. The training session comprised 3 blocks of 64 trials (total of 192 trials).

Stimulus Duration Testing—In duration testing, the stimuli were presented for fixed intervals of 1 s and 5 s, in addition to the 10-s duration. The testing session comprised a single block of 192 trials composed of 64 trials with each of the three duration intervals randomly presented. All of the trials were differentially reinforced and an incorrect response was always followed by a correction trial. Testing lasted for 20 sessions, in order for the birds to receive 20 exposures to each combination of stimulus, task, and duration.

Actual Stimulus Duration—As Figure 3 (right panel) illustrates, the birds had to peck a stimulus once after the duration interval elapsed to ensure that they were attending to the stimulus at its end. This procedure required that the length of the duration interval would exceed the nominal duration of 1, 5, or 10 s. This procedure could also introduce an inadvertent confounding variable: for example, if the actual duration on basic-level trials were longer than on superordinate-level trials, then that variable could account for disparities in discrimination performance. We therefore conducted a repeated-measures analyses of variance (ANOVA) with Stimulus Type (natural, artificial) and Task (basic, superordinate) as factors and the actual value of the stimulus duration interval as the dependent variable; we found no statistically significant differences that could account for the obtained discrimination performance. Moreover, the actual duration of each interval proved to be quite close to its nominal duration (1 s: 1.60 ± 0.02 ; 5 s: 5.15 ± 0.01 , 10 s: 10.01 ± 0.01).

Choice Delay Training—Before testing with different delay intervals, the pigeons were trained to perform the basic-level and superordinate-level discriminations after a 0-s delay. Figure 3 (left panel) illustrates the sequence of events in course of a basic-level choice delay trial. A trial began with the pigeon shown a black cross in the center of the white display screen.

Following one peck anywhere on the display, a training photograph appeared. The bird had to complete an observing response requirement (2 to 27 pecks for different pigeons) to the stimulus. The specific response requirement depended on the performance of the pigeon. If a bird failed to complete a session due to a high observing response requirement, then the peck requirement was decreased. If a bird was pecking but not meeting criterion in a timely fashion, then the peck requirement was increased to make failures more punishing. After that, the training image disappeared and the report buttons appeared, so that the pigeons had to make the choice in the absence of the training image. On a basic trial, four report buttons were shown; on a superordinate trial, two different report buttons were shown (cf. Figure 3, right panel). Basic and superordinate trials were randomly presented throughout a session. For two pigeons, the training stimuli came from Set 1; for the other two pigeons, the training stimuli came from Set 2.

If the pigeon's report response was correct, then food was delivered and the intertrial interval (ITI) ensued. The ITI ranged from 6 to 20 s for different pigeons. If the pigeon's report response was incorrect, then the house light and the monitor screen darkened and a correction trial was given. Correction trials continued until the correct response was made. All report responses were recorded, but only the *first* response of each trial was scored in data analyses.

The training session consisted of 3 blocks of 64 trials (total of 192 trials). For the original experiment (Lazareva et al., 2004), we planned to train all of the pigeons until they reached the 78/89 criterion (78% correct to each basic category and 89% correct to each superordinate category) in a single session, so that both percentages exceeded equal d' 's of 1.8. But, only one bird reached this criterion in a timely fashion (21 sessions); the other three birds failed to reach this criterion in 70 training sessions. So, the criterion level for these three pigeons was slightly lowered to d' 's of 1.7, which corresponded to 75% correct for each basic category and 88% correct for each superordinate category. This criterion level was maintained for all tests in the present experiment. The selected criterion had to be maintained during testing; if a pigeon's discrimination performance after 0-s delay fell below this level, then it was returned to training until it again reached criterion.

Choice Delay Testing—During testing sessions, pigeons were exposed to 1-s and 4-s choice delays in addition to the 0-s delay. The testing session comprised a single block of 192 trials composed of 64 trials with each of the three delays. All of the trials were differentially reinforced and an incorrect response was always followed by a correction trial. Testing lasted for 20 sessions, in order for the birds to receive 20 exposures to each combination of stimulus, task, and delay interval.

Behavioral Measures—Because two- and four-alternative forced-choice tasks involve different levels of chance performance (50% and 25%, respectively), direct comparison of accuracy scores was inappropriate. We transformed the percentage of correct choices to the signal detection measure d' (Algorithm 1, Smith, 1982). The d' score does not depend on the baseline probability of response (i.e., the chance level of discrimination corresponded to a d' of 0.00 for both tasks) and, therefore, allows for direct comparison between tasks. Tanner and Birdsall (1964) provide a detailed explanation of how d' controls for different numbers of alternatives. Swets (1964) offers an experimental estimation of d' for a yes-no procedure, a two-alternative choice procedure, and a four-alternative choice procedure, confirming the suitability of d' for these different procedures.

In addition, we conducted the statistical analyses reported below using an alternative correction procedure to adjust for different levels of chance performance. To do so, we divided the difference between observed performance and chance by the difference between perfect performance and chance. For example, 80% accuracy in the basic-level categorization task

would yield $(80-25)/(100-25) * 100 = 73\%$, whereas 80% accuracy in the superordinate-level categorization task would yield $(80-50)/(100-50) * 100 = 60\%$. The results of the analyses using this transformation led to the same conclusions as the results of the analyses using d' , and therefore are not reported here.

For all statistical tests, α was set at 0.05. Preliminary statistical analyses found significant main effect of Session for stimulus duration testing, indicating that average performance increased from Session 1 to Session 20. However, we found no significant interactions of Session and any other main effects for stimulus duration testing. Neither main effect of Session nor any interactions were significant for choice delay testing. Therefore, to simplify the analyses and the interpretation, all of the reported results were pooled across sessions.

Results

Stimulus Duration Testing

Figure 4 (top panel) shows that the pigeons performed the superordinate-level (2-choice) task more accurately than the basic-level (4-choice) task at all stimulus durations. The magnitude of the disparity appeared to increase as stimulus duration was decreased. More detailed analysis (Figure 4, bottom panel) revealed that the birds' discrimination of natural stimuli at the basic level fell far below their performance with artificial stimuli at the basic level (4-choice task) and with both natural and artificial stimuli at the superordinate level (2-choice task).

A full-factorial ANOVA with Duration, Task (basic, superordinate), and Stimulus Type (natural, artificial) as fixed factors and with Bird as a random factor, was used to test these observations. The ANOVA yielded a significant main effect of Duration [$F(2, 6) = 22.12$], indicating that the birds' overall performance deteriorated with shorter exposures to the pictorial stimulus. The main effect of Task [$F(1, 3) = 8.04, p = 0.066$] just failed to reach statistical significance. However, planned contrasts indicated that superordinate-level task accuracy was significantly higher than basic-level task accuracy for each stimulus duration [10 s: $F(1, 6) = 8.61, p = 0.026$; 5 s: $F(1, 6) = 8.96, p = 0.024$; 1 s: $F(1, 6) = 33.09, p = 0.001$], indicating that on average, the basic-level task required longer durations to achieve equivalent discrimination performance than the superordinate-level task. Although the magnitude of disparity between basic-level task and superordinate-level task increased slightly with briefer exposures (10 s: d' of 0.33; 5 s: d' of 0.35; 1 s: d' of 0.61), the Task x Duration interaction was not significant [$F(2, 6) = 2.60, p = 0.15$]. The absence of significant Task x Duration interaction might be interpreted as an indication that four-choice basic-level task is more difficult in general than two-choice superordinate-level task, but the further analysis with respect to effect of Task (natural, artificial) suggests that the nature of the stimuli played an important role as well (see Figure 4, bottom panel).

Both the main effect of Task [$F(1, 3) = 8.04, p = 0.066$] and the Task x Stimulus Type interaction [$F(1, 3) = 7.54, p = 0.071$] did not quite reach significance. Nevertheless, planned contrasts again indicated that on average the birds responded to artificial stimuli more accurately than to natural stimuli in the basic-level discrimination task, but that their responding did not differ in the superordinate-level discrimination task [basic natural vs. basic artificial: $F(1, 3) = 17.55, p = 0.025$; superordinate natural vs. superordinate artificial: $F < 1$]. The absence of a Stimulus Type x Duration interaction [$F(2, 6) = 1.0$] indicated that the magnitude of this disparity was not significantly affected by the decrease in stimulus duration. Discrimination of natural stimuli appeared to require more exposure than discrimination of artificial stimuli at the basic level, whereas accurate discrimination at the superordinate level appeared to require the same amount of exposure for both types of stimuli.

To sum up, we found that the basic-level discrimination was more strongly affected by brief durations of the pictorial stimulus than was the superordinate-level discrimination, suggesting differences in initial discriminability of the stimuli (Figure 4, top). Additionally, basic-level discrimination of natural stimuli required more processing time than basic-level discrimination of artificial stimuli (Figure 4, bottom); this result also indicates that the difference in accuracy cannot be explained by general difficulty of the task (four-choice task at basic level and two-choice task at superordinate level).

Choice Delay Testing

Figure 5 (top panel) shows that the superordinate-level (2-choice) task was discriminated better than the basic-level (4-choice) task at all choice delays, although the magnitude of the disparity seemed to rise from 0-s to 4-s delays. The natural and artificial stimuli categorized at the superordinate level were discriminated equally well, whereas at the basic level the discrimination of natural stimuli appeared to be lower than the discrimination of artificial stimuli (Figure 5, bottom panel).

To test the statistical significance of these observations, we conducted a full-factorial ANOVA with Delay, Task, and Stimulus Type as fixed factors and Bird as random factor. The main effect of Delay was significant [$F(2, 5) = 85.36$], indicating that birds' performance declined with increased delays. Although the main effect of Task [$F(1, 3) = 9.94, p = 0.051$] did not quite reach statistical significance, planned contrasts indicated that the superordinate-level discrimination was more accurate than the basic-level discrimination for all delays [0 s: $F(1, 6) = 41.85, p < 0.0001$; 1 s: $F(1, 6) = 42.29, p < 0.0001$; 4 s: $F(1, 6) = 158.77, p < 0.0001$]. The presence of a significant disparity in discrimination accuracy at the 0-s delay again suggests that the correct discrimination of stimuli at the basic level appears to require more processing time than at the superordinate level. The Delay x Task interaction [$F(2, 6) = 12.46$] was significant, indicating that the magnitude of the disparity between the basic-level task and the superordinate-level task increased with choice delay. This result supports differential forgetting in the basic-level and superordinate-level tasks, suggesting that the basic-level discrimination may be harder to retain than the superordinate-level discrimination.

Although the birds' performance on basic trials with natural stimuli trials was numerically lower than on basic trials with artificial stimuli at all delays (Figure 5, bottom panel), the ANOVA found no significant main effect of Stimulus Type [$F(1, 3) = 3.49, p = 0.16$] and no significant interactions [F 's < 1] involving Stimulus Type. Most importantly, the Stimulus Type x Delay interaction was not significant [$F < 1 = 0.04$], providing no evidence for differential forgetting of natural stimuli and artificial stimuli.

In summary, we found that the effect of choice delay on pigeons' discrimination in basic-level and superordinate-level tasks is consistent with both differences in initial discriminability and forgetting rate. However, we found no statistically significant evidence for a disparity in either initial discriminability or forgetting rate between the basic-level discrimination of natural stimuli and the basic-level discrimination of artificial stimuli.

Confusability of natural and artificial stimuli

Earlier, we reported that, during acquisition, pigeons more readily confused the two natural basic-level categories than the two artificial basic-level categories (Lazareva et al., 2004). Table 1 shows the mean percentage of confusion errors for natural and artificial stimuli at different stimulus durations and choice key delays. Natural basic-level categories were more frequently confused with each other than expected by chance (33%; 1 out of 3 choice keys represented a confusion error) at all stimulus exposure durations and choice key delays. With a single exception (choice delay of 1 s), the percentage of confusion errors for artificial basic-level

categories did not differ from chance. These results confirmed our prior report that our chosen exemplars of natural objects were more confusable than were our chosen exemplars of artificial objects.

Discussion

Basic-level discrimination versus superordinate-level discrimination

We found that pigeons' superordinate-level discrimination was less adversely affected by brief stimulus exposures than was their basic-level discrimination (Figure 4, top). We also found that delaying the choice response had a more detrimental effect on pigeons' basic-level categorization than on their superordinate-level categorization (Figure 5, top). The disparity between the basic-level and the superordinate-level discriminations was evident even at the 0-s delay, and it became more pronounced at longer delays, suggesting both differences in initial discriminability of the stimuli and differential forgetting.

Intuitively, these results seem sensible. Basic categories (e.g., *chair*) are often said to be more specific and to carry more information than superordinate categories (e.g., *furniture*). Consequently, more information may need to be extracted and retained to correctly classify an object at its basic level than at its superordinate level. Yet, the basic-level superiority hypothesis (Mervis & Rosch, 1981; Rosch & Mervis, 1975; Rosch et al., 1976) predicts the opposite result: Because superordinate categories presumably have lower within-category similarity than basic categories, one might expect that more features need to be encoded and retained to correctly classify an object at the superordinate level than at the basic level.

Research on rapid visual categorization suggests that people identify visual objects at the superordinate level more quickly than at the basic level (Large, Kiss, & McMullen, 2004; Van Rullen & Thorpe, 2001). For example, Van Rullen and Thorpe (2001) trained human participants to respond if a member of a superordinate category (an animal or a vehicle) was present in a photograph and to refrain from responding otherwise. Van Rullen and Thorpe reported that people can perform this task within 150 ms of stimulus onset and argued that basic-level categorization is extremely unlikely to produce still shorter latencies. A later study (Large, Kiss, & McMullen, 2004) using electrophysiological recording of brain activity found that people were faster to categorize line-drawing stimuli at the superordinate level than at the basic level. Moreover, analysis of the latency and amplitude of event-related potentials revealed that superordinate-level categorization diverged earlier (320–420 ms) from basic-level categorization in the course of visual processing, whereas subordinate categorization diverged later (450–550 ms) from basic-level categorization. Taken together, these studies suggest that objects may first be identified at the superordinate, rather than at the basic level; our results are consistent with this conclusion. Of course, our stimulus durations were much longer than those used by Thorpe et al.; additionally, we used a multiple-categorization approach instead of a go/no-go procedure. Nonetheless, we too found that less time is required for pigeons to correctly categorize a stimulus at the superordinate level than at the basic level.

Although we are not aware of any studies systematically exploring the effects of various delays on basic-level and superordinate-level categorization, the results of our delay testing are comparable to the results of our stimulus duration testing. We found that pigeons responded less accurately on basic-level trials at all delays including 0 s, again suggesting that basic-level categorization requires a more detailed representation to achieve equivalent discriminative performance. We also found that the basic-level discrimination fell more rapidly than the superordinate-level discrimination, thereby documenting differential forgetting in addition to a disparity in initial discriminability. In other words, the basic-level task appeared to be both harder to discriminate and to retain than the superordinate-level task.

Natural stimulus discrimination versus artificial stimulus discrimination

We found that brief presentations of the pictorial stimulus had the most detrimental effect on the basic-level discrimination of natural stimuli (Figure 4, bottom). The basic-level discrimination of artificial stimuli was less adversely affected by brief exposures, coinciding with the superordinate-level discrimination of both natural and artificial stimuli. In other words, the successful categorization of natural stimuli at the basic level seems to require longer stimulus durations than the successful categorization of artificial stimuli, but this difference is not present when stimuli are classified at the superordinate level. This result also indicates that the difference between basic-level discrimination and superordinate-level discrimination reported earlier cannot be ascribed to general difficulty of two tasks (four-choice task for basic-level discrimination and two-choice task for superordinate-level discrimination).

It is worth noting that some prior studies on rapid visual categorization failed to find any disparities in the categorization of natural and artificial stimuli (Large et al., 2004; Van Rullen & Thorpe, 2001). However, there are many procedural discrepancies that could account for this empirical disparity (species, stimulus material, experimental procedure, etc.). In any case, our results fit with prior categorization research reporting a dissociation in categorization between natural and artificial stimuli (see Martin & Caramazza, 2003, for a review). As well, our earlier research found several instances of dissociation between natural and artificial stimuli. We reported that pigeons discriminated artificial stimuli more readily at the basic level than at the superordinate level, but the opposite trend was true for natural stimuli (Figure 2; Lazareva et al., 2004). We also reported the results of later tests revealing that pigeons' categorization of natural stimuli may be controlled primarily by the overall shape of the object rather than by local features, whereas pigeons' categorization of artificial stimuli may rely primarily on local features rather than on the overall shape of the target object (Lazareva et al., 2006). In the present report, we again found a dissociation between natural and artificial stimuli in the basic-level categorization task: natural stimuli required longer stimulus durations than artificial stimuli.

Why might the natural stimuli have required longer stimulus durations? In our earlier study (Lazareva et al., 2004), the analysis of errors during acquisition suggested that pigeons may have perceived photographs of people and flowers as being more similar to each other than to either cars or chairs, whereas cars and chairs may have been perceived as being equally similar to every other category. This possibility can also explain the present results. If people and flowers are perceptually similar to each other, then more visual features would have to be extracted and retrieved to correctly discriminate these stimuli at the basic level than would be the case for artificial stimuli, producing more pronounced performance decrements with shorter stimulus durations and with longer delays. On the contrary, the correct basic-level discrimination of highly dissimilar cars and chairs may require less visual information extraction and retrieval; consequently, this discrimination should be less affected by either shorter stimulus durations or longer delays. Our analysis of confusion errors (Table 1) supports this possibility.

It has earlier been suggested that, in contrast to the categorization of natural stimuli, the categorization of artificial stimuli may be based on functional properties, leading to their behavioral dissociation (Damasio, 1990; Warrington & McCarthy, 1987). However, pigeons' categorization of photographs of cars, chairs, flowers, and people ought to be based solely on perceptual similarity within and between those four categories. Finding a natural-artificial dissociation in pigeons' categorization therefore suggests that people's categorization behavior may also be based on the perceptual coherence of the given categories, as other researchers have proposed (Gaffan & Heywood, 1993; Humphreys, Riddoch, & Quinlan, 1988; Lamberts & Shapiro, 2002; McRae & Cree, 2002). More research is clearly needed to elucidate this intriguing issue. Our own future studies will directly explore pigeons' perceived similarity

within natural and artificial categories, as well as the stimulus features controlling their categorization of natural and artificial stimuli in both basic and superordinate discrimination tasks.

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Figure 1.
A set of 4 of the 64 stimuli that were chosen from four basic-level categories: cars, chairs, flowers, and people.

Figure 2.

Mean number of sessions required to reach d' criterion throughout training on basic and superordinate tasks (from Lazareva et al., 2004).

Figure 3.
The schematic sequence of events for basic-level delay trial (left panel) and superordinate-level duration trial (right panel).

Figure 4. Mean discrimination performance in the stimulus duration test averaged by level of categorization (upper panel) and by type of stimuli (lower panel).

Figure 5. Mean discrimination performance in the choice delay test averaged by level of categorization (upper panel) and by type of stimuli (lower panel).

Table 1

Percentage of confusion errors for natural basic-level categories (flowers and persons) and artificial basic-level categories (cars and chairs) committed during stimulus exposure testing and choice delay testing

Duration in seconds	Natural basic-level categories		Artificial basic-level categories	
	M	SD	M	SD
Stimulus exposure testing				
10	47.6*	16.2	30.6	16.2
5	45.5*	16.6	30.4	18.7
1	42.3*	12.8	38.3	20.2
Choice delay testing				
0	57.8*	15.4	33.0	9.2
1	47.5*	8.1	46.6*	15.1
4	42.9*	12.6	39.2	16.4

Note: An asterisk denotes means that were significantly different from chance (33%) according to one-tailed *t*-test (*df* = 7).