Pigeons can discriminate "good" and "bad" paintings by children

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Abstract Humans have the unique ability to create art, but non-human animals may be able to discriminate "good" art from "bad" art. In this study, I investigated whether pigeons could be trained to discriminate between paintings that had been judged by humans as either "bad" or "good". To do this, adult human observers first classified several children's paintings as either "good" (beautiful) or "bad" (ugly). Using operant conditioning procedures, pigeons were then reinforced for pecking at "good" paintings. After the pigeons learned the discrimination task, they were presented with novel pictures of both "good" and "bad" children's paintings to test whether they had successfully learned to discriminate between these two stimulus categories. The results showed that pigeons could discriminate novel "good" and "bad" paintings. Then, to determine which cues the subjects used for the discrimination, I conducted tests of the stimuli when the paintings were of reduced size or grayscale. In addition, I tested their ability to discriminate when the painting stimuli were mosaic and partial occluded. The pigeons maintained discrimination performance when the paintings were reduced in size. However, discrimination performance decreased when stimuli were presented as grayscale images or when a mosaic effect was applied to the original stimuli in order to disrupt spatial frequency. Thus, the pigeons used both color and pattern cues for their discrimination. The partial occlusion did not disrupt the discriminative behavior suggesting that the pigeons did not attend to particular parts, namely upper, lower, left or right half, of the paintings. These results suggest that the pigeons are capable of learning the concept of a stimulus class that humans name "good" pictures. The second experiment showed that pigeons learned to discriminate watercolor paintings from pastel paintings. The subjects showed generalization to novel paintings. Then, as the first experiment, size reduction test, grayscale test, mosaic processing test and partial occlusion test were carried out. The results suggest that the pigeons used both color and pattern cues for the discrimination and show that non-human animals, such as pigeons, can be trained to discriminate abstract visual stimuli, such as pictures and may also have the ability to learn the concept of "beauty" as defined by humans.

Introduction

As far as can be determined, creating art has been considered to be an activity unique to humans. Our creative abilities have been documented since the cave drawings of our ancestors more than 30,000 years ago (Lewis-Williams 2002). Presumably, a sense of aesthetics, or the ability to comprehend and appreciate fine art, is considered to be a uniquely human ability. Although there have been some studies on the drawing ability of non-human animals (see Zeller 2007), their ability to conceptualize aesthetics has not been tested. Here, I concentrated on perceptual or discriminative aspects of the art rather than motor aspects or drawing performance in animals. Fechner von (1876), the

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founder of experimental aesthetics, argued for a bottom-up approach to the concept of beauty instead of a top-down approach in the metaphysical tradition of aesthetics. To understand our sense of beauty, he developed psychophysical measurement methods that are still used in the study of sensation and perception. Later, Berlyne (1976) introduced four methods to the experimental investigation of aesthetics, namely verbal judgment, psychophysics, statistical analysis, and measurement of exploratory behavior. The last aspect is purely a behavioral method and is thus, applicable to animal research. A new alternative to the experimental investigation of aesthetics is a neuroscientific approach, called "neuroaesthetics" (Zeki 1999). Using functional brain imaging techniques, Zeki has shown that specific brain regions are activated when humans view visual art. For instance, the anterior cingulate gyrus is activated when a subject perceives something as beautiful. If there is a biological component to the sense of beauty, perhaps it is possible to trace the evolutionary origin of aesthetics. There are examples in nature where animals must make qualitative judgments of a conspecific or of something created by a conspecific. For example, the female bowerbird bases much of her "decision" to mate with a male conspecific on the quality of the bower nest he has made (Uy et al. 2001). The same can be said about a female songbird judging the quality of a potential mate's song (Draganiou et al. 2002). Human aesthetics has been studied from evolutionary (Voland and Grammer 2003), neuroscientific (Zaidel 2006), and cognitive (Solso 2003) perspectives, but experimental researches with non-human animals are quite rare. One serious problem in experimental animal research of beauty is identifying a definition of stimulus "beauty". That is, in humans, beauty is not an objectively or physically defined concept. Consequently, our criterion of beauty depends on individuals, cultures, era, and so on. Beauty from one era may not be beautiful during a different era, just as beautiful art for one culture might be considered ugly for a different culture. In addition, some contemporary conceptual art or message art may not be perceived as beautiful for certain people. However, even though "beauty" is a socially constructed concept, there seems to be certain common features or properties that exist at a basic level.

Our concept of beauty appears to have two basic properties. The first is that it has hedonic value. That is, humans derive pleasure from viewing aesthetically pleasing art and experience negative emotions from aesthetically displeasing art. Because of this, art can have reinforcing properties for humans. Studies of sensory reinforcement have demonstrated that not only biologically relevant stimuli (e.g., food, water, etc.) but also sensory stimuli (e.g., switching on a lamp for rats; Berlyne 1969; looking at an electric toy train for chimpanzees; Butler 1953, etc.) can have reinforcing effects for animals. Previously, we investigated the reinforcing properties of music for Java sparrows and showed that subjects preferred classical music such as Bach or Vivaldi to modern music such as Schoenberg or Carter (Watanabe and Nemoto 1998). Interestingly, two species of primates, marmosets and tamarins, showed no preference for musical stimuli (McDermott and Hauser 2007). Preference for particular complex auditory stimuli observed in humans and songbirds may be related to the ability to produce complex vocal communication (language or songs) in these species. In the case of visual stimuli, Rensch (1957) described preference for regular, symmetrical patterns in capuchin monkeys. This finding was later confirmed by Anderson et al. (2005). There is, however, no experimental work on the reinforcing properties of visual art in animals.

Another aspect of beauty is that it has discriminative stimulus properties. People can tell the difference between "good" or beautiful paintings and "bad" or ugly paintings as well as comfortable music from unpleasant noise. That is, we have the ability to form a sensory concept or category of what is aesthetically pleasing. Behaviorally, a concept is defined as a generalization within a stimulus class and discrimination between classes. Herrnstein and Loveland (1964) were the first to find evidence for a complex visual concept in pigeons. Since that time, several studies have demonstrated the pigeon's ability to form visual concepts (for example, Herrnstein et al. 1989; Wasserman et al. 1988; Watanabe 1988; Watanabe et al. 1995), although there is still a lot of discussion on similarity and dissimilarity between human concept formation and those acquired by animals. For example, in one study, pigeons learned to discriminate many different patterns of triangles from three randomly arranged lines but, testing with distorted triangle patterns, such as partial triangle or a triangle pattern made of dots, showed that pigeons were under a different stimulus control from that of humans (Watanabe 1991). Of course, the human definition of a triangle is a rule that can be described verbally. On the other hand, pigeons have to establish nonverbal definition-like rules through behavioral experience alone. Comparing the pigeons' patterns of responding after training with multiple exemplars and after training with a single exemplar suggests that exposure to multiple exemplars may be essential to the formation of an artificial geometrical concept based on a definition-like rule. The stimulus-response (S-R) approach may explain concept discrimination in terms of summation of miniature generalizations from each item used in the discriminative training. Thus, discrimination training consisted of physically different exemplars should be hard to produce a concept-like discrimination base on miniature generalization from each exemplar. Previously, we demonstrated that pigeons could successfully discriminate paintings according to artists or artistic style (Watanabe et al. 1995; Watanabe 2001b). In the current study, I examined the

ability of pigeons to discriminate paintings on a different rule, namely "beauty". When a human, a curator for example, collects impressionists' paintings, the collection may contain Monet, Renoir, etc. but may not contain Picasso or Braque. There is a stylistic similarity among the paintings of impressionists. When another curator wants to collect "beautiful" paintings, the collection may contain Monet or Renoir but also Picasso, Braque or Hokusai. There must be a rule or a collection of rules by which we decide which paintings are more aesthetically pleasing than others, but it is hard to clarify them. Understanding the concept of beauty as the summation of discrimination of independent exemplars of beautiful pictures (S-R approach) is theoretically possible but difficult to examine empirically.

In the case of "beauty", as I wrote earlier, its criterion may depend on age, culture, and individuals. However, we may have a common sense of beauty for rather relatively less sophisticated paintings such as those drawn by schoolchildren. There should be some common perceptual features in these "beautiful" paintings. If so, perhaps nonhuman animals can learn the human concept of "beauty" as a discriminative stimulus class based on perceptual similarity. In order to examine this, I used drawings of children as stimuli in the present experiments. Sometimes children's pictures are evaluated from highly sophisticated artistic view, but what I preferred scoring of these paintings by an elementary school teacher of art and by ordinary adults. This was the basic subjective evaluation of naïve pictures by ordinary people rather than that by professional artists. I then trained pigeons to discriminate these "good" versus "bad" paintings by schoolchildren and examined possible features of "beauty". The purpose of these experiments is not to obtain an anthropomorphic understanding of the discriminative behavior of pigeons, but to analyze the human concept of beauty with discriminative training or ontogenetic contingency in pigeons. I also examined discriminative behavior to modified versions of the original painting stimuli. First, the size of the paintings was reduced to test robustness of the discriminative behavior against visual angle, second the paintings were changed to grayscale presentation to test color cue, third the paintings were modified by mosaic processing to test local pattern cue, and finally the paintings were partially occluded to test the possibility of stimulus control by a particular part of the paintings.

Successful discrimination of paintings in pigeons might be based on fine visual discrimination such as texture discrimination (Cook 1992). In Experiment 2, I trained pigeons on discrimination between watercolor paintings and pastel paintings. In this case, a set of "good" and "bad" watercolor paintings and a set of "good" and "bad" pastel paintings were used as stimuli. Thus, the pigeons had to discriminate the paintings based on the difference in painting medium. After the discriminative training, the subjects were tested with novel paintings for generalization. Then, four other tests employed in Experiment 1 were carried out to examine cues of the painting medium discrimination.

Experiment 1: discrimination of "good" pictures

Methods

Subjects

Four experimentally naïve pigeons (ages 2–4 years) were obtained from the Japanese Society for Racing Pigeons. They did not have any previous operant conditioning experience. They lived in cages individually under a 12L: 12D light cycle and their weights were maintained at 80% of their free feeding weight. Water was freely available in the cages. The subjects were treated in accordance with the guidelines of the Japanese Society of Animal Psychology.

Stimuli

I obtained examples of paintings by children from an elementary school in Tokyo. Watercolor and pastel paintings drawn by pupils were divided into "good" and "bad" paintings according the evaluation of the school art teacher. Fifty-seven paintings by children (ages 9–11 years) that were graded A, C, or D by the classroom art teacher were obtained. I considered the teacher's evaluation of an A as "good" and C or D as "bad". The paintings were then photographed using a digital camera (SONY Cybershot DSC-F828) under natural lighting. Adobe Photoshop (version 8.1) was used to modify the brightness of pictures that looked too dark or too bright. No other adjustments were applied to the images. Then, printed pictures (16 × 24 cm) were made. Ten adults (Students and professors in Keio University, ages 20–57 years, with normal color vision) were individually asked to classify them as "good" and "bad". There was no time limit for the classification. I then selected 15 "good" paintings and 15 "bad" paintings as follows. All ten observers had to agree that a painting was "good" in order for a picture to be selected as a "good" painting stimulus. In the case of disagreement between the observers' classification and the teacher's evaluation, the painting was not selected. Finally, the number of watercolor and pastel paintings was approximately matched. I used ten "good" and ten "bad" paintings for training and used the remaining five of each group as the novel paintings for the generalization test. The pictures were edited using Power Point software so that the size of the painting on the monitor was 23.5 × 17.5 cm.

Apparatus

Standard operant chambers with a modified pecking window were used (30 × 25 × 30 cm, MED). The birds could see a liquid crystal display monitor (37 × 24 cm) of a computer (Power PCG4, iMac2.1, 800 MHz) through the rectangular transparent key (10 × 7 cm). The distance between the window and the monitor was 20 cm. There was a liquid crystal shutter (an electronic shutter) between the key and the monitor.

Procedure

Preliminary training

All subjects were trained to peck the key by an autoshaping procedure. Then, they were trained on a variable interval (VI) schedule. The value of the VI schedule was gradually increased to 20 s. During this preliminary training, no painting stimuli appeared on the TV monitor. After the subjects showed steady responding on VI 20 s, discriminative training began.

Discriminative training

During discrimination training, ten "good" (S+) and ten "bad" (S−) paintings were presented two times each in accordance with the Gellerman series to avoid three successions of S+ or S−. Half of S+ and S− were pastel and the remaining half was watercolor. Pecking at the "good" pictures (S+) was rewarded by a four s period of access to a feeder after a variable interval with a mean of 20 s (Variable Interval 20 s schedule), whereas pecking at the "bad" pictures was not rewarded. After the 20 s presentation of a painting, the monitor was darkened for 5 s by a liquid crystal shutter and then the next trial began. Any peck on the key during the 5 s period prolonged the darkened period for 5 s, that is, a chained differential reinforcement of zero rate (chain DRO 5 s) schedule was effective during the darkened period. This training continued until the birds emitted more than 90% of their total responses to the "good" paintings (the discrimination ratio) for two successive sessions. After the discrimination training, the subjects received five different types of tests.

Generalization test

First subjects were tested with 20 paintings consisting of five "good" and five "bad" paintings used in the discrimination training and another five new "good" and five new "bad" paintings they had never seen before. Three of the new "good" and two of new "bad" paintings were pastel, and the remaining new paintings were watercolor. Figure 1
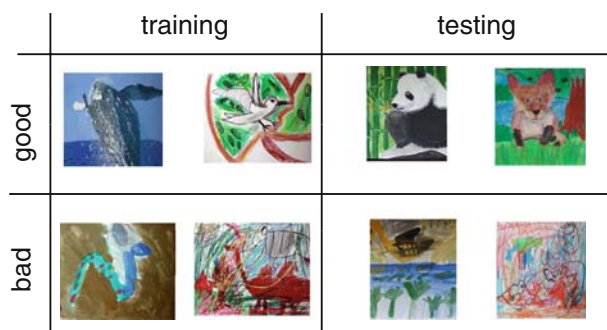
Fig. 1 Examples of the stimuli. The left four images are examples of stimuli used during the discriminative training and those on the right were used in the generalization test as novel stimuli

shows examples of the training and testing stimuli and all stimuli used in the generalization test can be seen in the Electronic supplementary materials S1. Each stimulus was presented two times for 20 s separated by a 5 s dark period and the order of presentation was based on a Latin square. Pecking to any stimuli was extinguished and DRO schedule during the dark period was effective.

The following additional tests were carried out in the following order. The procedures of the test were identical to the discriminative training procedures except for modification of the stimuli, that is, the subjects received reinforcement during the tests. Between the testing, discrimination training was carried out to maintain the discrimination ratio of at least 90%.

Size reduction test

The purpose of this test was to examine the effect of stimulus size. We can identify "good" paintings in a museum but also those on a catalog book in which each painting is printed in small scale. Here, the size of the stimulus paintings was reduced from 23.5 × 17.5 to 6.0 × 4.5 cm. The other procedures were identical to the discriminative training.

Gray scale picture test

The purpose of this test was to examine the importance of color in discriminating "good" drawings. Both humans and pigeons have sophisticated color vision, hence they may use color cues for discrimination of "good" paintings. The paintings were displayed using the grayscale mode of the computer in this test. All other procedures were identical to those described for the discriminative training.

Mosaic stimuli test

The third test was a mosaic test. The purpose of this test is to examine the importance of stimulus pattern as a cue for discrimination. By applying the mosaic function to the

original painting stimulus, the average and brightness color information was preserved but the pattern information was distorted depending on degree of mosaic processing. Specifically, the original paintings were modified to consist of 10, 20, 40, and 80 pixels per mosaic unit using Adobe Photoshop (version 8.1) software. Each unit had averaged color information in its area but no information of shape in the area. This third test consisted of four separated subtests. The subtests were carried out in increasing series starting at 10 pixels to 80 pixels. The other procedures in this test were identical to those described in the discriminative training.

Partial occlusion test

The purpose of this test is examination of possibility of discrimination based on particular part of drawings rather than the overall image. To occlude the stimulus images, a gray cardboard covered the upper, lower, right or left half of the paintings. Thus, the forth test consisted of four separated subtests. These subtests were administered in random order. Once again, the remainder of the procedures were identical to those described in the discriminative training.

Data analysis

Analysis of variance tests (ANOVAs) and *t* tests were used for data analyses. There were four categories of stimuli in the generalization tests, namely old-"good", new-"good", new-"bad" and old-"bad", each consisting of five paintings. "Old" meant stimuli used for the discriminative training and "new" meant those never presented during the training. For each bird, the relative response to these four categories was calculated by dividing the number of responses to each category by the total number of responses to all four categories. A paired samples *t* test was used for statistical analysis of the difference between the new-"good" and new-"bad" in the generalization test. A paired samples *t* test was also used for the change of discrimination ratio in the grayscale test. Discrimination ratios in the test and that in the session just before the test were used for the analyses.

   A two-factor analysis of variance (ANOVA) was used for analysis of the difference in responding within the new-"good" categories. This analysis was conducted due to the possibility that there might be particular stimuli to which the pigeons responded often. In addition, there might be individual differences in responding to these new stimuli. The stimuli and the subjects were used as factors. A single factor ANOVA was used for analysis of the mosaic test. The discrimination ratio for each mosaic test was used for the analysis.

Results

All of the birds learned the discrimination (average 22.5 sessions; range 18–32 sessions). I tested the pigeons' responses to ten paintings used for the training and ten new paintings in the generalization test. As shown in the upper panel of Fig. 2, the subjects responded often to the old and to the new "good" paintings, and less often to the old and new "bad" paintings, although they showed some decrement in responding to the new "good" paintings. There was no statistically significant difference in responding between the old and new "good" paintings (two-tailed *t* test, $t = 0.399$, $df = 4$, $P = 0.71$), or between the old and new "bad" paintings ($t = 1.11$, $df = 4$, $P = 0.31$). In contrast, there was a significant difference in responding between new "good" and new "bad" paintings (two-tailed *t* test, $t = 6.22$, $df = 3$, $P = 0.008$). Thus, the pigeons responded to new "good" and "bad" paintings differentially, indicating that the subjects successfully generalized their ability to discriminate "good" paintings from "bad" paintings. The lower panel of Fig. 2 shows a relative response ratio, calculated by dividing the number of responses to each novel
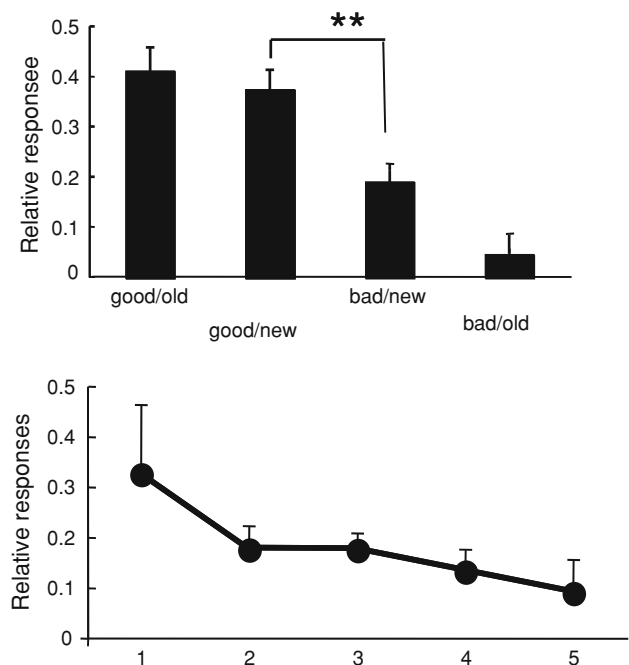

Fig. 2 *Upper* generalization test after "good" versus "bad" painting discrimination training. The vertical axis shows the average of relative responses to the four types of paintings, calculated by dividing the number of responses to each type by the total number of responses. The subjects clearly discriminate "good" versus "bad" paintings even for stimuli they had never seen before. *Lower* relative responses to five novel "good" paintings. Relative response was calculated by dividing the number of responses to each novel "good" stimulus by total number of responses to all novel "good" stimuli. The vertical axis is relative response within the novel stimuli. **$P < 0.01$, paired *t* test. Small bars indicate standard deviations

Fig. 3 *Upper* results of the mosaic test. The vertical axis is the discrimination ratio, calculated by dividing the number of responses to "good" painting by the total number of responses to "good" and "bad" paintings. *Lower left* results of size reduction test and grayscale test. *Lower right* results of partial occlusion tests. *Small bars* indicate standard deviations
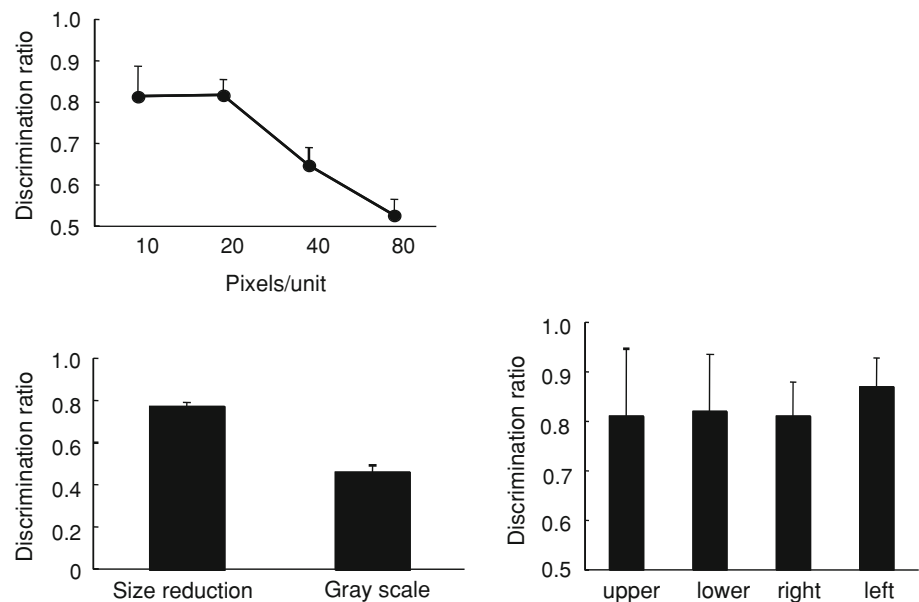
"good" stimulus by the total number of responses to all novel "good" stimuli, for five novel "good" stimuli. The pigeons emitted more responses to particular stimuli. A two-factor ANOVA (stimuli × subjects) showed a significant effect of the stimuli ($F4, 19 = 3.65$, $P = 0.04$) but no significant effect of subjects ($F3, 19 = 0.36$, $P = 0.78$).

After the generalization test, the subjects received ten different tests. In most of the cases, the subjects maintained their discriminative behavior in the discriminative training session after each test. However, when the subjects did not attain the criterion of discrimination in the training session just after the tests, they needed just one more session to reach the criterion again. As shown in the lower left panel of Fig. 3, when we reduced the size of the stimulus paintings (6.0×4.5 cm), the birds discriminated them as well as when they were the original size. On the other hand, when we presented grayscale paintings, their discrimination was reduced to almost chance level. There was a significant difference in the discrimination ratio between the grayscale test and the training session just before the test ($t = 6.48$, $df = 4$, $P = 0.007$). Thus, color must be one cue for their discrimination. As shown in the upper panel of Fig. 3, when mosaic processing was varied among 10, 20, 40, and 80 pixels per mosaic unit, their accuracy of discrimination was reduced depending on the spatial frequencies (F $3,12 = 5.74$, $P = 0.011$). The discrimination ratio for 80 pixels was at chance level (mean = 0.52, SD = 0.07). A single group t test revealed no significant difference from chance level ($t = 0.59$, $df = 3$, $P = 0.59$). Because the change of spatial frequency modified the shape while maintaining the global color information, the results indicate that the birds used the pattern as a cue for their discrimination. Partial occlusion did not impair the discriminative

behavior (the lower right of Fig. 3). A single-factor ANOVA showed no significant effect of the position of the occlusion ($F3, 15 = 0.24$, $P = 0.87$), suggesting that no particular region of paintings provided discriminative cues.

Discussion

The results clearly demonstrated that the pigeons acquired the visual concept of the stimulus class that was classified as "good" pictures as subjectively judged by human observers. This does not mean that the pigeons perceived the pictures as "beautiful" as we do, but instead suggests that they discriminate beautiful paintings as one class of stimuli associated with food reward. Furthermore, the present results did not confirm which cues pigeons used for their discrimination of beauty. However, both impairment of the discrimination by removing color and the decrement of discrimination ratio depending on the degree of mosaic processing suggest that both color and shape cues were used for their discrimination, whereas discrimination ability was not impaired when the stimulus paintings were reduced in size.

Gray scale versus color stimulus

In the case of discrimination of artists, Monet vs. Picasso for example, pigeons maintained their discrimination in the grayscale test (Watanabe et al. 1995). Therefore, pigeons did not use color cue for discrimination of artists but used it for discrimination of beauty. To discriminate the "good" pictures from "bad" pictures they employed a strategy different from that used for the artistic style discrimination.

Mosaic versus original stimulus

The pigeons showed decrements in discrimination depending on the degree of mosaic processing after the discrimination of artists (Watanabe 2001b). This result is congruent with the present results of the mosaic processing.

Occlusion versus whole stimulus

Maintenance of the discriminative behavior in partially occluded condition suggests that the pigeons saw whole paintings rather than a particular part of them.

Although not all of the paintings used in this experiment were representational pictures, we can easily recognize objects of picture in most of the "good" paintings as shown in Fig. 1. The pigeons should not have a chance to see objects of the paintings such as a whale, monkey, horse, etc. Previous research suggests that pigeons do not see human and pigeon stimuli when they are presented as cartoon pictures (Cellera 1980; Watanabe 2001a). It is not plausible to assume pigeons' ability to understand "good" paintings as paintings of what they represent and yet, in the generalization test, the subjects responded to particular stimuli more often than other stimuli. This observation suggests that there may be a typical "good" painting. The question still remains, is this true for humans?

In order to learn more about this question, I interviewed the teacher of the art class and the human participants on their criteria for "good" and "bad" paintings. Defining "good" and "bad" pictures was not simple, even for the teacher. He pointed out technical qualities, such as using different types of brushes for watercolor and the variety of colors, but also explained that technical "goodness" is not the only criteria. Most of the human participants said that they easily identified objects in the picture when it was "good". These interviews suggested that the category or concept of beauty is polymorphous. The next experiment examined the discrimination of painting medium, pastel or watercolor.

Experiment 2: discrimination of watercolor and pastel

Previous experiments have shown that pigeons can discriminate the fine visual differences between artificial stimuli based on texture alone (Cook 1992). Using the children's paintings, we trained pigeons to discriminate watercolor from pastel paintings. The purpose of Experiment 2 was to examine the flexibility of discrimination using similar stimuli. In Experiment 1, pigeons discriminated paintings based on human judgment of "good", here pigeons were trained stimuli based on differences in texture by painting medium.

Methods

Subjects

I trained eight new experimentally naïve pigeons (ages 1–4 years) on a watercolor versus pastel discrimination task. The birds were housed identically to those in Experiment one.

Stimuli

I selected paintings that were correctly classified as watercolor or pastel by all of the ten adult human participants. Half of the pastel and watercolor paintings were selected from paintings that were judged as "good" and the remaining half as "bad".

Procedure

After shaping to peck the key and VI schedule training, the subjects were trained on discrimination using a procedure similar to that used for the beauty discrimination in Experiment one. Four pigeons were trained to peck the watercolor paintings while the remaining four were trained to peck the pastel paintings. The training procedure was identical to that in Experiment one. The training continued until the subjects reached the criterion of discrimination.

Tests

After achieving the criterion for discrimination, the subjects received a generalization test in which 20 paintings consisting of five pastel and five watercolor paintings used in the discrimination training and another five new pastel and five new watercolor paintings were presented two times in accordance with a Latin square. All of the stimuli used in the generalization test were given Electronically in supplement material S2. Responding to any stimuli was extinguished. Then, size reduction, grayscale, mosaic processing, and partial occlusion tests were conducted. Procedures of these testing were identical to those in Experiment one. The subjects received the usual discriminative training between the testing sessions to maintain their discrimination. As before, when the subjects did not show more than 90% discrimination ratio, additional discriminative training was carried out until they showed 90% discrimination again.

Results

The pastel S+ group required 25 sessions and the watercolor S+ group 10 sessions. However, there was no significant

Fig. 4 *Upper* generalization test after pastel versus watercolor discrimination training. *Open* and *closed bars* indicate Pastel S+ and watercolor S+ groups, respectively. *Wc* and *pt* means watercolor and pastel, respectively. *Lower* response to novel pastel paintings (Pastel S+ group) and five novel watercolor paintings (watercolor S+ group). **P < 0.01, paired *t* test. *Small bars* indicate standard deviations
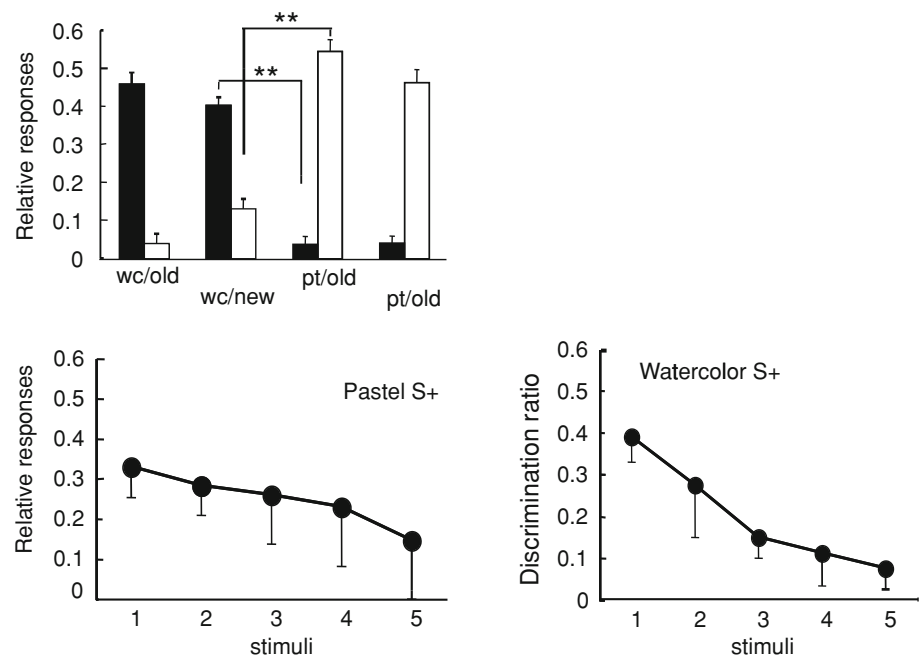
difference between the two groups (two-tailed *t* test, *t* = 2.01, *df* = 6, *P* = 0.09). Watercolor and pastel provided sufficient information for discriminating paintings. The stimuli used for the discrimination were the same in both groups. Thus, responding to pastel and not to watercolor was easier than doing the opposite of this. Figure 4 shows results of the tests with new paintings. The pigeons clearly discriminated the new paintings. There is a significant difference between novel pastel and novel watercolor paintings (*t* = 9.19, *df* = 3, *P* = 0.003 for water-color group and *t* = 6.44, *P* = 0.007 for the pastel group). The lower panels in Fig. 4 shows the relative response ratio to each novel pastel or watercolor painting during the generalization test. There was no significant effect of individual or stimuli in the pastel S+ group (two-factor ANOVA *F*3, 19 = 0.048, *P* = 0.98, and *F*4, 19 = 0.62, *P* = 0.65), while the ANOVA did show a significant effect of stimuli in the watercolor S+ group (*F*4,19 = 6.62, *P* = 0.005). Thus, the subjects trained on watercolor discrimination emitted more responses to particular watercolor stimuli even though they maintained discrimination between the pastel and watercolor. As shown in the lower left of Fig. 5, reduction in size did not affect their discrimination but the grayscale test stimuli showed lower discrimination performance. Thus, color is an important cue for watercolor versus pastel discrimination. Because the mosaic processing of the four test levels affected the discrimination (Fig. 5 upper panel), pattern cues also played a role in the discrimination (two-factors ANOVA, *F*1, 24 = 0.32, *P* = 0.57 for groups; *F*3, 24 = 16.27, *P* = 0.000005 for mosaic processing; *F*3, 24 = 1.51, *P* = 0.23 for the interaction). The discrimination for the 80 pixel stimuli was at chance level (mean = 0.47,

SD = 30.16 for pastel group and mean = 0.56, SD = 0.06 for watercolor group). A single group *t* test revealed no significant difference from chance level (*t* = 1.82, *df* = 3, *P* = 0.17 for the watercolor group, and *t* = 0.30, *df* = 3, *P* = 0.78 for the pastel group). Partial occlusion did not impair the discrimination performance (lower right of Fig. 5). A single-factor ANOVA showed no significant effect of the position of the occlusion (*F*3, 15 = 1.53, *P* = 0.25 for the pastel group and *F*3, 15 = 1.71, *P* = 0.22 for the watercolor group). Thus, the particular part of the paintings did not control the discriminative behavior of the subjects.

Discussion

The results showed that pigeons could discriminate watercolor paintings from pastel paintings. The pastel group accomplished the discrimination task a little bit faster than the watercolor group. Because the exact same stimuli were used for both groups, this difference is probably due to the feature positive effect. Both the watercolor S+ group and the pastel color S+ group demonstrated generalization to novel stimuli, hence they learned not only the discriminative stimuli used in the training but also categories of painting medium. Reducing the size of the paintings did not affect the discriminative behavior, which is in agreement with the "good" and "bad" discrimination in Experiment 1. The grayscale test and mosaic test suggest that the pigeons used both color and shape information to discriminate the painting medium. As shown in Experiment 1, the subjects used both color and pattern cues as critical features in

Fig. 5 *Upper* results of the mosaic test. The vertical axis is discrimination ratio, calculated by dividing the number of responses to pastel (or watercolor) painting by total number of responses to pastel and watercolor paintings. *Lower left* results of size reduction test and grayscale test. *Lower right* results of partial occlusion tests. *Open* and *closed bars* indicate Pastel S+ and watercolor S+ groups, respectively. *Small bars* indicate standard deviations
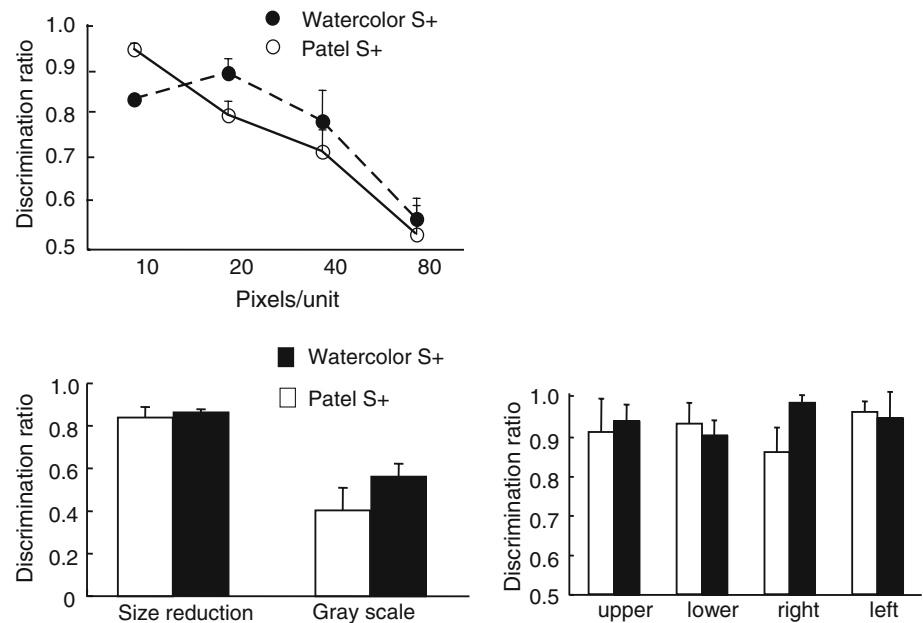
beauty discrimination. Thus, pigeons might employ similar cues for beauty discrimination and texture discrimination. The partial occlusion test also gave similar results to those found in the beauty discrimination test.

General discussion

The present results demonstrate that pigeons can be trained to discriminate concept, or stimulus class of "beauty" based on human subjective classification. In other words, "beauty" in the present experiment has common discriminative stimulus elements that can be shared by humans and birds. We cannot, however, say that pigeons and humans have a similar aesthetic evaluation of visual arts in general. Exemplars of "good" and "bad" paintings were obtained from one elementary school in Tokyo, not random sampling of paintings in general. Experiment 2 showed discrimination of painting medium using similar paintings to those in Experiment 1. Due to group differences in Experiment 2, it is hard to conclude which of the discrimination tasks, namely "good" versus "bad" painting or watercolor versus pastel, is easier to learn for pigeons.

The present experiments did not reveal much detail about the visual strategies the pigeons used to discriminate these stimuli or the underlying neural mechanisms. Nevertheless, these two aspects are very important to clarify similarities and dissimilarities between human and avian visuocognitive abilities.

Although both humans and birds demonstrate apparently similar visual cognition here, behavioral and/or neural mechanisms of such discrimination could be different. Lea et al. (2006) pointed out that pigeons' visual cognitive strategies might be different from humans. For example, humans are good at global processing of visual stimuli, while pigeons are good at local processing (Covato and Cook 2001). When pigeons were trained to discriminate movie sequences in which an object moved in front of the background or the background moved behind the objects, the pigeon learned the background movement, while the object movement was much easier to recognize for human observers (Goto and Lea 2003). Pigeons are also better at mental rotation of shapes in comparison to humans (Hollard and Delius 1982). After learning to discriminate slide images with and without people, pigeons maintained their discrimination in a scrambling test in which small elements of the original slides were randomly mixed (Aust and Huber 2001). In contrast, human observers cannot detect people in such scrambled pictures. However, there are also experiments that have demonstrated similarities in visual cognitive strategies between humans and pigeons. Gibson et al. (2007) examined the perception of 2-dimensional projections of 3-dimensional objects in humans and pigeons. After discrimination of the 2-dimensional shapes generated from 3-dimensional objects, regions of the shapes crucial for discrimination were determined by a technique called "bubbles", with randomly arranged occludes. That is, during testing, only portions of the image were visible. These portions of visibility are called bubbles. Research has shown that edge co termination is crucial for the determination of 3-dimensional objects, for both humans and pigeons.

These studies suggest that humans and pigeons may use similar visual cues to identify "good" paintings in Experiment 1 and painting medium in Experiment 2. Both species do, however, show a similar stimulus class in their

discriminative behavior. In other words, the human concept of "good" paintings has perceptual features that can be learned even by pigeons. However, the identification of beauty in professional arts by sophisticated artists should be different from that of scoring "good" and "bad" drawings of children in elementary school. In the latter case, discrimination of "good" paintings is presumably based on "low-level" perception rather than aesthetic theory.

Differences in visual strategies between humans and birds are still not well understood, but it is clear that they use different visual pathways to process information about object recognition and location. Most mammals have a relatively less developed superior colliculus, suggestive of relatively poor vision compared to predominately visual animals, such as primates. Humans and other primates are rather exceptional mammals that have well-developed visual abilities: in particular, primates have a well-developed thalamofugal pathway for visual cognition. On the other hand, birds have a large optic tectum (superior colliculus) and a well-developed tectofugal pathway for sophisticated visual cognition. More than 90% of the ganglion cells in a bird retina (2 million such cells) send their axons to the contralateral tectum (Mpodozis et al. 1995). In higher visual centers, the mammalian pallium has laminar (layered) structures, while the avian pallium has compartmentalized structures, cell clusters. Thus, humans and pigeons use different visual pathways and different pallial structures to process visual information. The present experiments demonstrated that the pigeons could discriminate human visual categories despite such differences in brain organization. In other words, considerably different brain architectures can provide similar functions regarding complex visual discriminations.

Creation of art has three basic components: (1) beauty must be discriminated, that is it must have the property of being separated into classes or categories, (2) beauty must be enjoyed, that is it must have a reinforcing property, and (3) finally, motor skills must bridge between the first two components. The present experiments show that pigeons are capable of the first component. Perhaps, each species has its own sensitivity to the reinforcing properties of sensory stimuli. Such species-specific sensory reinforcement might be shaped through phylogenetic contingency of the specie. The fur and feathers of some animals have reinforcing properties for humans even though they may be intended for something more crucial to survival, such as sexual selection of the particular species. Whether humans and animals share similar sensibility to sensory events is still an unanswered question, but the present results demonstrate that the discriminative stimulus property of beauty for humans can be learned by pigeons through training or ontogenetic contingency. Further studies are necessary to confirm whether or not non-human animals have the capacity for visual aesthetics in a similar way humans do.

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