

## VIDEO DISPLAY FOR STUDY OF AVIAN VISUAL COGNITION: FROM PSYCHOPHYSICS TO SIGN LANGUAGE

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**ABSTRACT:** We demonstrated four different ways of using video systems for research in avian visual cognition: 1) recent developments of high vision TV systems made it possible to use the video system for psychophysical studies. Visual acuity measured with such a video system was comparable to those obtained by more traditional methods; 2) using image processing software, we could display unnatural animals, such as chimeras on the TV screen. We also reported that pigeons did not discriminate partially occluded conspecifics; 3) effects of exposure to visual stimuli upon on-going behavior were examined using suppression and conditioned suppression procedures; and 4) discrimination of moving images, namely two words of Japanese Sign Language, are reported.

Humans and most avian species are animals with sophisticated visual capacity. Ancestors of primates and that of birds might share some common ecological niche, namely jumping from tree to tree to find food and to avoid predators. Visual information processing is required for estimating distance from tree to tree and detecting something partly occluded by leaves. Comparative psychologists have shown not only psychophysical but also higher cognitive capacity in birds. Pigeons can discriminate many different kinds of natural categories such as humans, trees, leaves, conspecifics, food, paintings and so on (see Bischof and Zeigler, 1993, for a review of recent studies).

Since the research of Herrnstein and Loveland (1964), a slide projector has been the most common way of presenting complex visual stimuli. The slide projector is easy to control and allows fine resolution on a screen. However, the researcher has to repeatedly set slides into

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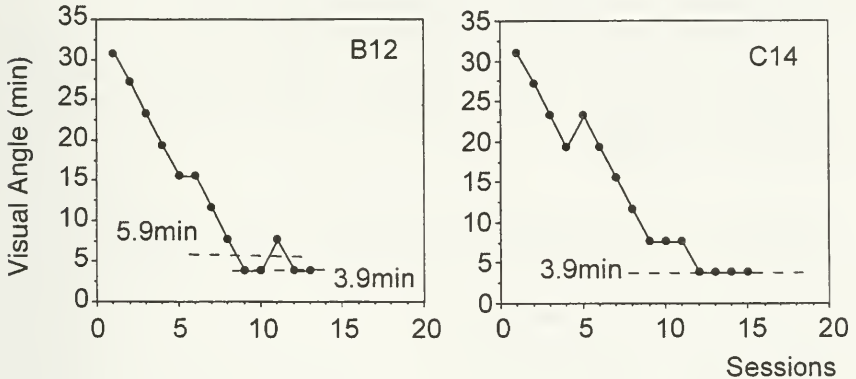
the carousel and modification of the photopicture, such as production of a chimera picture, is time consuming. Recently researchers has employed the TV monitor as a stimulus presenting device. Random access to a particular frame is easily carried out with a TV monitor connected to a computer and image processing software makes it possible to produce complex visual stimuli on the monitor screen. In this paper we demonstrated four different ways of using a video system for research into bird visual cognition, and finally discuss some problems associated with video display for animal research.

## 1. USE OF A VIDEO MONITOR IN PSYCHOPHYSICAL STUDIES

Many studies have measured visual acuity in birds using a slide projector as a stimulus presenting device. For example, Hodos *et al* (1976) reported that the visual acuity of the pigeon was 1.9 min of arc. A potential problem of using video monitors in psychophysical studies is limits resulting from the number of scanning lines and pixels. The NTSC TV system, the conventional TV system, has 525 scanning lines and 330000 pixels. The PAL TV system has 625 scanning lines. These limitations make it difficult to use such TV systems for psychophysical studies in which finer resolution is required. NHK, the national broadcasting company in Japan, has recently developed a new High-vision system. It has 1125 scanning lines and about 2 million pixels. Thus, the resolution is approximately five times greater than the conventional video system. We have employed this system to measure the visual acuity of the pigeon (Furuya, 1996). The bird was trained to locate its head at a specified position (as detected by a photosensor) in front of two circular pecking locations in which the stimuli were displayed on the TV monitor. The distance between the head position and the monitor screen was 16cm. When the pigeon located its head correctly, a horizontal stripe (width of 1.45 arc min) or plain grey pattern appeared on the screen. The mean brightness of the stripes was identical to that of the grey pattern (54 cd/m<sup>2</sup>). A peck on the screen produced a food reward when the stripes appeared, while no reward was given when the grey pattern appeared. Each training session consisted of 60 trials. If the birds responded more than 80 percent correctly, the stripes were changed to finer ones in the next session.

Figure 1 shows examples of the results. The visual acuity of B12 was between 3.9 - 5.6 min. and for C14 was 3.9 min. Hodos *et al* (1976) reported a minimum acuity threshold of 1.9 min at a luminance

of  $214 \text{ cd/m}^2$ . However, at luminance levels comparable to the present study ( $54 \text{ cd/m}^2$ ), the brightness-acuity function shown by Hodos *et al* (1976) shows a visual acuity of approximately 3 min. Thus, the visual acuity measured by the video system is close to that measured using projected gratings and a slide projector.



**Figure 1.** Example results of the visual acuity test. The stripes become finer when the subjects achieved more than 80 percent correct.

## 2. MODIFICATION OF THE VISUAL STIMULUS

A TV monitor has also been used for the presentation of more complex stimuli, such as images of conspecifics for pigeons (Watanabe, 1992) and chickens (Evans and Marler, 1991) or jumping spiders (Clark and Uetz, 1990). Development of imaging processing software makes it also possible to modify the visual stimuli. Thus, we can produce biologically impossible chimeric images of animals, such as a pigeon with a hawk head. Watanabe & Jian (1993) trained Bengalese finches to discriminate between individual conspecifics using a still video player (Konica KP-400). During discrimination training, still images of the birds were displayed on a TV monitor in conjunction with the sound of contact calls.

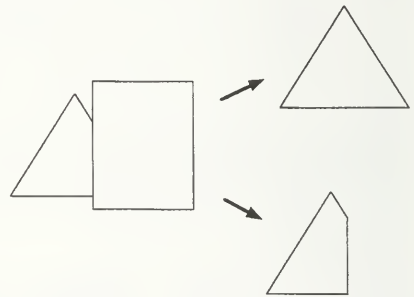
After the subjects learned the discrimination, the image of finch A was presented with the calls of finch B and the images of finch B were presented with A's calls to determine whether visual or auditory cues controlled the discriminative behavior. The results demonstrated that the visual cue was dominant. Then, we made a chimeric image of A's head with B's body and vice versa using image processing software

(Adobe Photoshop). When, we presented these chimeric stimuli, some of the subjects showed discrimination by contact calls. That is, when the normally dominant visual cues did not give enough information, the finches employed auditory cues for individual discrimination. Brown and Dooling (1993) reported that the patterns of stripes in the face was the most salient visual recognition feature for budgerigars.

We then analyzed recognition of conspecifics in pigeons in the following two experiments. The first involved detection of a partly occluded conspecific, and the second was discrimination between a pigeon and a starling.

### EXPERIMENT 1: DOES THE PIGEON SEE A HIDDEN BIRD?

Cerella (1980) reported that pigeons could not discriminate a hidden triangle if presented as shown in Figure 2. However, a triangle is probably an unfamiliar stimulus for a pigeon. We wanted to know whether a pigeon could discriminate an image of another pigeon when that image was partially occluded, ie., would the birds perceive a hidden pigeon rather than just a part of one.



**Figure 2.** Occlusion of a triangle. Humans can see the occluded triangle shown on the left.

### METHOD

#### *Subjects*

Eleven experimentally naive pigeons were used. They lived in individual individual cages made of stainless wire mesh (30x34x35cm). Water and minerals were freely available but access to mixed grain was restricted to maintain about 80 percent of their free feeding weights. Illumination of the animal room was kept 12L:12D cycle artificially.

#### *Apparatus*

An operant chamber (30x30x30cm) with a transparent rectangular pecking key (10x7.5cm) was used. There was a TV monitor just behind

the pecking key. The image appeared on the TV screen connected to a laser disk player (TEAC,LVA2000).

### *Procedure*

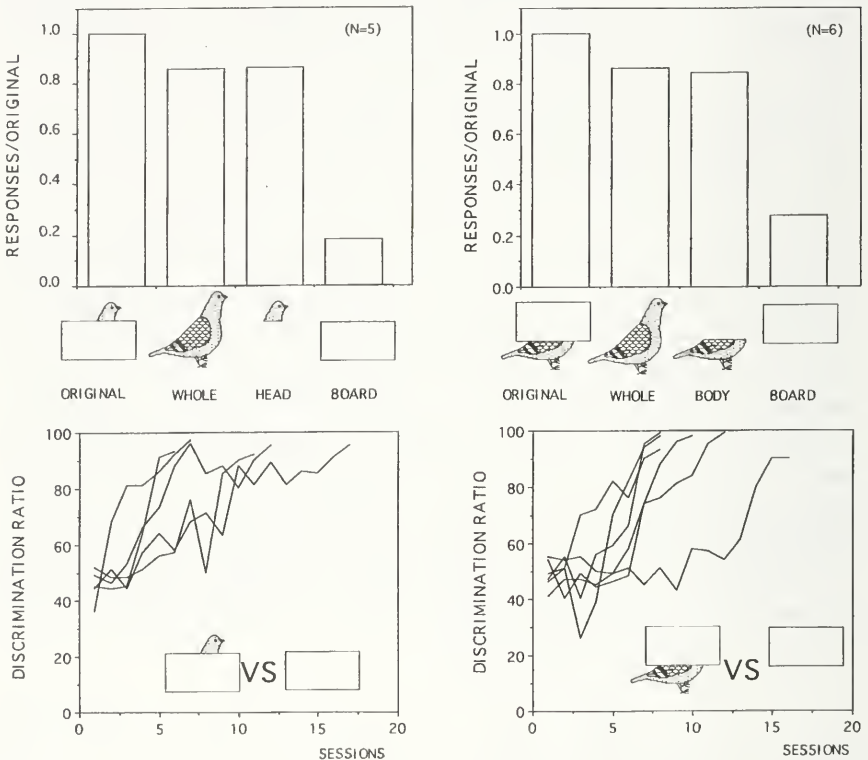
All pigeons were trained to peck the TV screen by an autoshaping procedure, and then were trained on a Variable Interval (VI) 30 sec schedule. The subjects were then divided into two groups. The "head" group received discriminative training between an image of a pigeon's head above a grey board and the grey board without the head, and the "body" group between an image of pigeon's body under the board and the board without the body (Figure 3). Response to the stimulus with a part of a pigeon was reinforced on VI30 sec while that for the plain board was extinguished in each group. One discriminative training session consisted of 40 random presentations of two stimuli, each lasting 30 sec separated by a 5 sec blackout period. This training continued until the subject showed a discrimination ratio of more than 90 percent, calculated by dividing the number of responses to the stimulus associated with reinforcement by the total number of responses to both stimuli, for two successive sessions. They the received a test with the original images, a whole image of a pigeon and part of the pigeon. These stimuli were presented randomly five times each. No reinforcement was given during the test. If pigeons saw a hidden bird behind the board, they should have responded more often to a complete bird than to the original stimulus. On the other hand, if the pigeons attended to just a head or a body, they should have responded to the test stimuli non differentially.

## RESULTS AND DISCUSSION

Figure 3 presents the results of the two groups. The subjects learned the discrimination tasks in approximately 20 sessions. The response to each test stimulus was expressed as a relative response to that emitted by the original stimulus. The subjects trained to peck to the "head" above the board responded more often to the original stimulus, to the whole image of a pigeon and to the head of the pigeon than to the board ( $F(3,16)=18.3, p<0.0001$ ). There was no statistically significant difference between responses to the three stimuli containing part of a pigeon, while the response to the plain board was significantly less than that to each of the other stimuli ( $p<0.001$  for each stimulus

pair, Fisher's PLSD ).

The subjects trained to respond to a pigeon's "body" under the board also showed a similar tendency. They pecked often at the original, the whole body and body part of the pigeon  $F(3,20)=10.27$ ,  $p<0.0005$ ). There was no statistically significant difference among the three stimuli containing the pigeon's body but a significant difference between the plain board and the other stimuli ( $p<0.001$  for each pair, Fisher's PLSD).



**Figure 3.** Results of the hidden bird discrimination. The lower two panels show individual discrimination learning curves of the "head" group (left) and the "body" group (right). Upper panels show the mean results of the tests.

These results suggest that the presence of a part of the pigeon is enough to control the subjects' discriminative behavior. The responses observed in the present experiment are considered as similar to the phenomenon of "feature positive" discriminations (Jenkins and Sainsbury, 1970). In GO/NOGO discrimination training, it is easier to learn to respond to a stimulus with an added feature than to learn to respond to a stimulus without the feature. This phenomenon has been

well demonstrated with many species including humans. The feature, in this case the head or the lower half of the body, controlled the discriminative behavior. In other words, the subjects did not complete the partly occluded pigeon. This finding confirms earlier reports by Cerella (1980) and Sekuler *et al* (1996) in which geometric figures were used as stimuli.

## EXPERIMENT II: CUES FOR SPECIES DISCRIMINATION

Testing with chimera stimuli has also been used to analyse the discrimination of complex stimuli (Lea and Ryan, 1990; Cook *et al*, 1990; Brown and Dooling, 1993). Using a slide projector, we trained pigeons to discriminate between the heads of two conspecific individuals (Watanabe and Ito, 1991). We then cut and pasted parts of printed photographs of the birds to make chimera slides. The results of tests with such chimera stimuli suggested that there was no single cue for the individual discrimination.

Recent image processing software can easily produce similar types of modified stimuli. In the present experiment, pigeons were trained to discriminate between visual images of a pigeon and of a grey starling. Subsequently, responses to two different kinds of modified images were examined; one involved the exchange of facial parts, such as a chimera, and the other involved morphing of two images.

## METHOD

### *Subjects*

Four experimentally naive pigeons were used. They were maintained at 80 percent of their free feeding weights.

### *Apparatus*

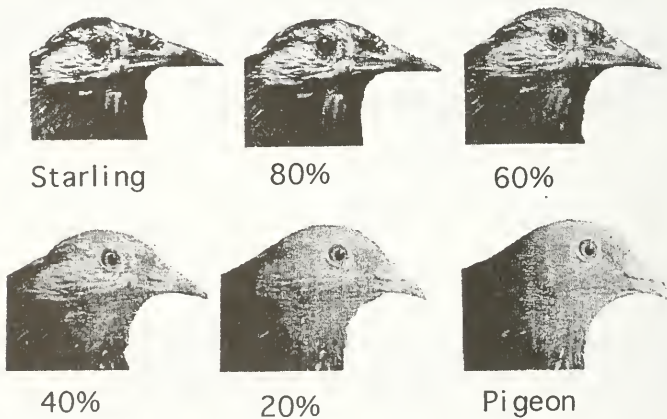
The apparatus used in the experiment 1 was used.

### *Procedure*

The apparatus and methods were similar to those used in experiment 1 except for the stimuli. The subjects were divided into two groups of two. For one group (pigeon group), an image of a pigeon's

head was used as the stimulus associated with reinforcement while an image of a starling's head was used as the stimulus not associated with reinforcement. The other group (starling group) was trained on the reverse task, that is, the starling was the positive stimulus and the pigeon was the negative one. After the subjects learned the discrimination task, they were tested with two series of stimuli. The first series involved exchanging parts of the two images. Thus the birds were exposed to the original image, or this image but with a beak or eye or feathers of the other bird. One test consisted of 5 presentations of these stimuli each lasting 30 sec separated by a 5 sec blackout period. No reinforcement was given during the test.

The second series involved morphing. A photoshop morphing program was used to produce the testing stimuli. Twenty positions were selected as feature points on the images and the program then mixed the shape and color of these corresponding points at 20, 40, 60, and 80 percent mixing rate (Figure 4). One test consisted of 6 presentations of these six stimuli, including the original pigeon and starling, and each presentation was 30 sec separated by a 5 sec blackout period. Again no reinforcement was given during the test.

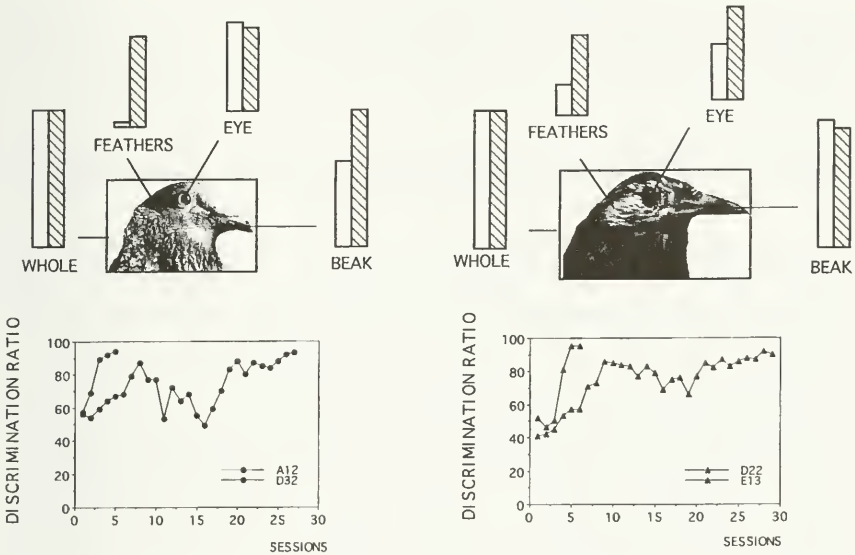


**Figure 4.** Stimuli produced by morphing. The top left is the original 100 percent starling and the bottom right is the original 100 percent pigeon.

## RESULTS AND DISCUSSION

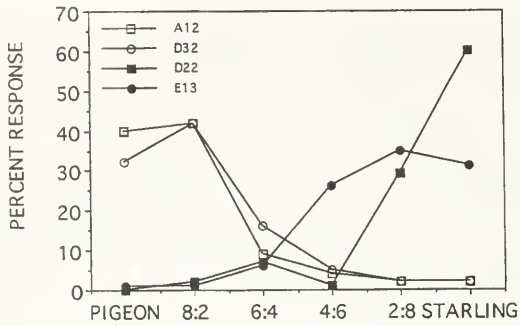
Figure 5 shows the results. Two birds, one in each group, learned the task in 5 or 6 sessions. Other two needed more than 25 sessions.

Responses to the chimera stimuli were expressed as a percentage of the number of responses to the original stimulus. As shown in the figure, the exchange of beak or eyes did not greatly depress responding. On the other hand, exchange of the feathers had a more severe consequence. This might be because the starling has distinctive white feathers on its cheek and the subjects used this feature for the pigeon vs. starling discrimination. In other words, they did not need a complete image to detect the discriminative stimuli.



**Figure 5.** Results of the conspecific discrimination. The lower panels show individual learning curves of pigeon positive (left) and starling positive (right) discriminations. The upper panels show individual results of the whole or body part (feathers, eye or beak) exchange test - for example, "Eye" in the left panel means the responses to the image of a pigeon with the eye of starling by two separate subjects.

Figure 6 presents results of the morphing test. The birds were able to discriminate the images when the mixing rate was 80 percent. One bird trained to respond to the starling discriminated the starling within the 60 percent picture. Morphed images were not only determined by mixing rate but also by the number and the locations of feature points. Thus, the critical mixing rate at 80 percent found in this experiment is not a general rule of morphing discrimination and further research using a wire-framed model or other well defined model will be necessary to obtain conclusive results.



**Figure 6.** Mean results of the morphing generalisation test. The extreme left and right are the complete pigeon and the complete starling respectively.

### 3. SUPPRESSION OF OPERANT BEHAVIOR BY VISUAL STIMULI

The experiments described above used still images. The other type of stimulus is a moving stimulus. Evans *et al* (1993) has shown that computer-generated animation simulating aerial predators elicited alarm calls in chickens. Jungle fowls exhibited social facilitation of feeding when exposed to videotapes of conspecific feeding (Mcquoid and Galef, 1993). Chickens produce alarm calls more frequently when other conspecifics are presented. This facilitative effect is called an audience effect. Videotapes with sound were more effective in producing audience effects on alarm calling in chickens (Evans and Marler, 1991). Display of moving images may suppress ongoing behavior.

Pollution by pigeons is a major problem in big cities such as Tokyo. Contamination by defecation and nesting is particularly serious in railway stations, temples and in big apartment buildings. Therefore, it is important to deter pigeons from populated areas. A loud noise or other aversive stimulus is not suitable in areas where people are living. Thus, if some visual stimulus was shown to deter pigeons, it could be a convenient tool to control their behavior. In fact, there are several commercially available visual stimuli designed to deter birds, such as a balloon with a big eyeball. However, the effects are not permanent.

We tried to find such a visual stimulus (Furuya and Watanabe, 1996). At first pigeons were trained on a Variable Interval 60 sec schedule in a conventional operant chamber. After the subjects showed a steady response, moving images were displayed on a side wall of the operant chamber (25x30 cm) with a video projector.

The stimuli were made by a screen saver program and recorded on

a video tape. Three different stimuli were made, namely a rotating eyeball (diameter 95mm), frost and fire (10 - 250 cm in diameter), and a flying bird (52x29mm). These tapes were played back continuously and an electromagnetic shutter connected to the video projector controlled presentation of the stimulus. The stimulus appeared at 5 min intervals for 1 min. One session lasted 30 min. The suppression ratio was calculated by dividing the number of responses emitted during the stimulus presentation period by the number of responses recorded during a 1 min period immediately before the stimulus presentation.

One stimulus appeared until the subjects showed less than 10 percent suppression ratio. A conditioned emotional response procedure was then administered, that is, the presentation of the stimulus was followed by a brief electric shock (0.3mA, 10msec) through a grid floor for one session. After one session of conditioning, the stimulus appeared without electric shock in the following sessions.

Figure 7 presents an example result of such an experiment. This bird showed suppression of operant responding when exposed to new stimuli, but the suppression rapidly disappeared upon repeated presentations. Two possibilities have to be pointed out about suppressive effects of the visual stimuli. In this experiment all stimuli were projected on the side wall. Projection on the ceiling of the chamber may produce different results, because birds usually see aerial predators overhead. The frost and fire was selected from the screen-saver software because it has a most striking effect for human observers, but other patterns may more effective for pigeons. The electric shock suppressed the response again and this time, the effect continued longer than the previous exposure. There is, however, no significant difference among the types of stimuli.

These results suggest that it is difficult to deter pigeons for a long time using a visual stimulus alone and that pairing of the visual stimulus with an electric shock lengthens the aversive deterrent effect of the visual stimulus.

#### 4. DISCRIMINATION OF MOVING IMAGES

Many animals use complex movements, such as dance display, as releasers. Therefore, they can discriminate complex movements at least in the case of fixed action patterns. Watanabe *et al* (1993) trained Bengalese finches on the discrimination of moving video images of two individuals. Two of four finches learned the discrimination and showed

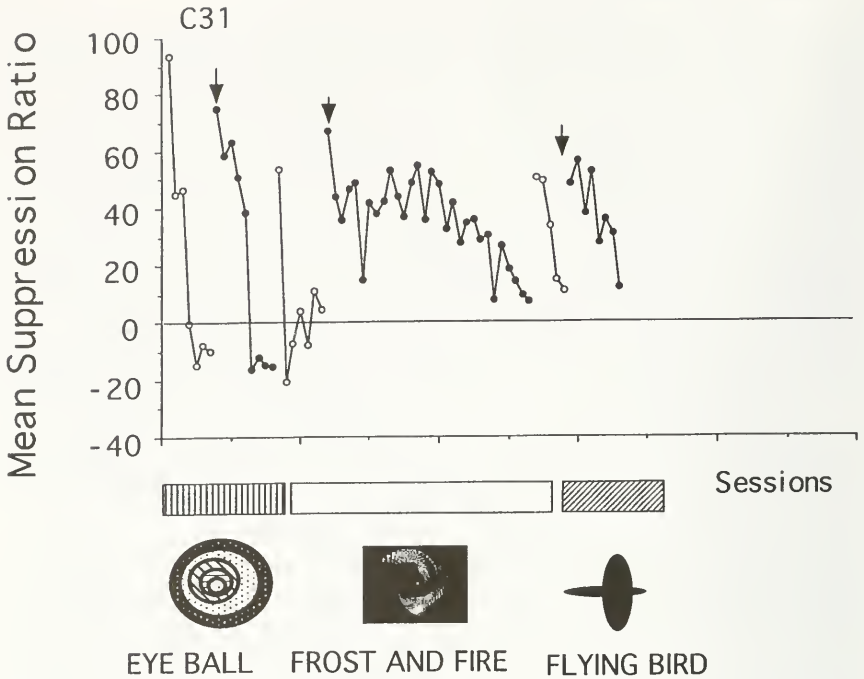


Figure 7. Suppression of operant by visual stimulus. Arrows indicate an electric shock session.

transfer of the discrimination from the moving images to still images. Although pigeons do not show any social behavior to life-size moving video images of conspecifics (Ryan and Lea, 1994), they can discriminate movements of a conspecific on a video display (Dittrich and Lea, 1993). Dolphins and sea lions also discriminate instructions made from a combination of movements by the trainer (Gisner and Schusterman, 1994; Herman *et al*, 1990; Shyan and Herman, 1987). There may be species differences in the perception of moving images or differences in perception may depend on the procedures. In the following experiment we tried to train pigeons to discriminate movements used in human sign language.

### EXPERIMENT III: DISCRIMINATION OF JAPANESE SIGN LANGUAGE WORDS BY PIGEONS

Gardner and Gardner (1969) reported that chimpanzees can learn American Sign Language to communicate with people. In the present experiment, two pigeons were trained on a discrimination between two

words of Japanese sign language.

## METHOD

### *Subjects*

Two pigeons were used. They were maintained at about 80 percent of their free feeding weights.

### *Apparatus*

The experimental apparatus was identical to that in Experiment I.

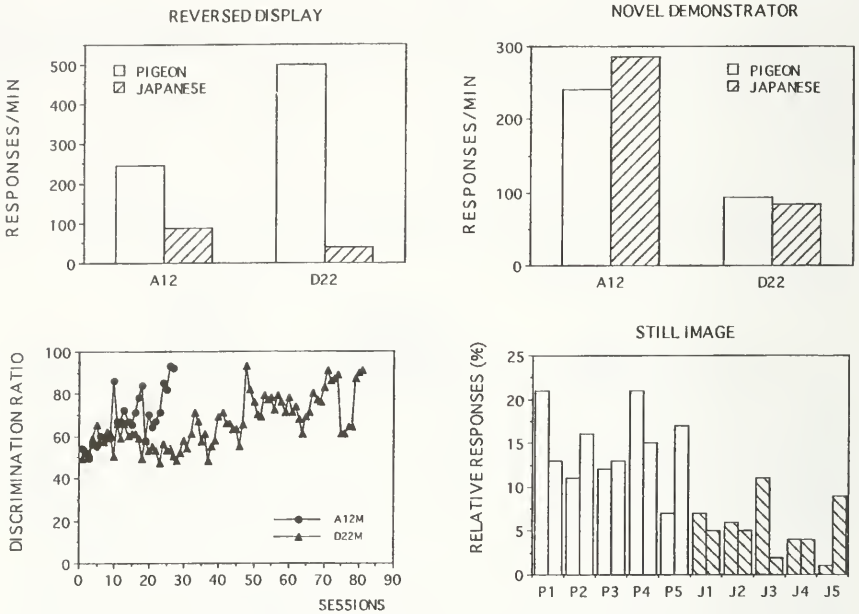
### *Procedure*

We trained pigeons to discriminate between two words of Japanese Sign Language. One is "Japanese" and the other is "pigeon". The duration of movement of each word was 2 sec. Repeated demonstration of these words by a particular person was recorded on a laser disk and displayed on a TV monitor. Pecking responses to the screen were reinforced when one word ("pigeon") appeared on it, while pecking was extinguished when the other word ("Japanese") appeared. One stimulus presentation period was 30 sec followed by a 5 sec blackout period. This training continued until the subjects achieved more than a 90 percent discrimination ratio for two successive sessions. They then received three tests. The first was the reverse play test in which two movements were displayed in reverse, i.e, from the end to the beginning. The second was the still image test in which five postures of each word were selected and these still images were displayed instead of moving images. The third was a transfer test in which the two words demonstrated by a novel person were displayed. No reinforcement was available in these tests. The subjects received training sessions between the tests to maintain their discrimination.

## RESULTS AND DISCUSSION

One pigeon learned this discrimination task within 30 sessions but the other bird required more than 85 sessions (Figure 8). The birds clearly discriminated the two movements when they were displayed in reverse. They maintained the discrimination even when still images

were displayed, but they failed to discriminate the words when they were demonstrated by a new person. Thus, the pigeon did not learn the concept of a sign language word but rather learned discrimination of the movement of a particular person.



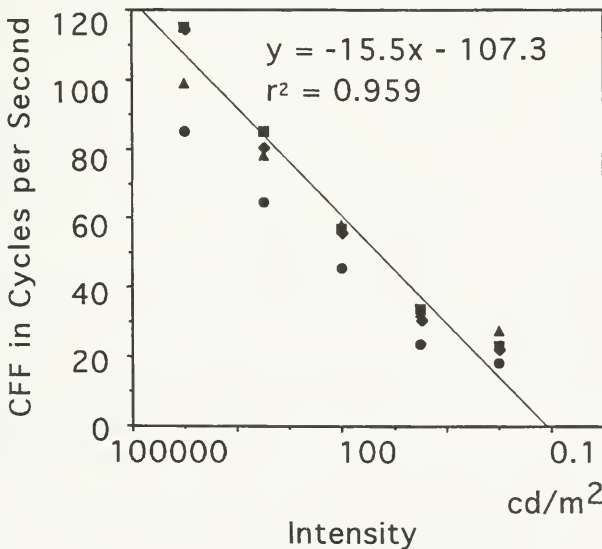
**Figure 8.** Discrimination of the sign language for the words "pigeon" and "Japanese". Lower left: learning curves of two subjects; lower right: mean results of the still image test. "P" and "J" indicate postures selected from movements of "pigeon" and "Japanese" respectively. Upper left: test of reverse play back. Upper right: test with a novel demonstrator.

Dittrich and Lea (1993) trained pigeons to discriminate video images of a moving pigeon and a still pigeon, and found generalization to movement of novel birds. This observation suggests that pigeons can form a concept of motion. Using a live pigeon as the discriminative stimulus, Millard (1979) succeeded in training pigeons to discriminate responding patterns of conspecifics. Furthermore, the pigeons showed generalization to the responding patterns of a novel stimulus bird. Pigeons can recognise social behavior of other pigeons in natural settings, so they should recognize a articular movement regardless of which bird displayed it. Although their social behavior may have more

distinctive features than in our Japanese sign language stimuli, the present results together with other previous studies suggests that pigeons' ability to discriminate movement is specialized to the movement of a conspecific. Recently, we trained pigeons on Johanson's stimuli discrimination, that is, movement of a few dots pasted on a pigeon's body (Oomori and Watanabe,1996). The birds learned to discriminate the movement of three dots pasted onto an a live pigeon from the movement of those pasted onto a toy dog. However, they did not show transfer of discrimination from movements of dots to real movement. Thus, they did not perceive the movements of these three dots as the movement of a real bird.

## GENERAL DISCUSSION

One important point to consider in video display is the CFF (critical frequency of fusion). The scanning rate of a TV screen is 60 Hz, even in the Hi-vision system. Powell (1967) reported that the CFF for pigeons was 145Hz at a brightness of 100000  $\text{cd}/\text{m}^2$ , and 100Hz if the brightness was reduced to 100  $\text{cd}/\text{m}^2$ . Figure 9 shows the CFF curve calculated from the data of four subjects reported by Powell (1967). The average brightness of commercial TV is around 60-70  $\text{cd}/\text{m}^2$  and an extrapolated value of the CFF at this brightness is 58



**Figure 9.** Relationship between stimulus intensity and critical flicker fusion calculated from data presented by Powell (1967).

cycles per sec. Thus, the high CFF in pigeons may not be a crucial disturbing variable if the brightness of the screen is dim.

Another critical problem is the discrepancy between the color system of a TV and the avian color system. The avian retina contains at least four different photopigments, while a color TV system is based on a mixture of only three components. Spectral sensitivity of the pigeon is also very different to human spectral sensitivity. Because TV systems produce color matched to the human color system, we can see rather natural color on TV but pigeons may not. TV systems are adequate for some monochromatic image studies but comparison of natural color and TV color is open for further research.

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