

Discrimination of videos of conspecific behavior in pigeons

Senior honors thesis for the Department of Psychology

Joanna L. Kornstein

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Like all social animals, pigeons must be able to recognize and categorize conspecific behavior to respond appropriately. Previous studies with digital animated models have indicated that pigeons are able to discriminate on the basis of action categories. In this experiment, two pigeons were trained to discriminate between video clips depicting different categories of pigeon behavior. In a go/no-go procedure, pigeons responded to video clips of conspecifics walking or courting in the motion condition, or random static frames from the same videos in the static condition. Stimuli were conditionally reinforced so that walking was positive and courtship was negative in the motion condition, with reversed assignments in the static condition. The purpose of the conditional reinforcement was to analyze the relative importance of motion cues based on the difference in performance on the two conditions. Both pigeons learned the dynamic discrimination faster and more accurately than the static discrimination. Transfer tests were conducted to further explore which cues were important in the discrimination of the videos. One pigeon demonstrated partial transfer of the motion discrimination to new videos of each behavior. Both pigeons demonstrated strong transfer to videos played in reverse and to videos with randomized frame order, and no transfer to blurred videos. These results indicate that the pigeons did not use motion cues in the discrimination, and that having multiple frames in the dynamic condition but only a single frame in the static condition may have caused them to discriminate videos better than images. These results imply that pigeons discriminate actions in recorded videos in a different manner than actions of digital models.

### **Introduction**

Like all social animals, pigeons must be able to recognize and respond to the actions of conspecifics in situations such as mate selection, social foraging, and agonistic interactions. However, it is difficult to study empirically what mechanisms animals use to recognize the conspecific actions due to our lack of control over the stimulus. No two examples of a particular behavior appear completely identical. For example, a pigeon foraging looks different depending on the angle and distance of the observer, the individual pigeon, the surface, speed, and specific motions involved. Thus, the simplest way for pigeons and other animals to recognize a variety of behaviors is to categorize them according to different cues.

Studies of human action recognition indicate that humans are extremely adept at recognizing the actions of others and require very little information in order to do so. We can even recognize actions based only on the movements of a few points of light on the body (Johansson, 1973). In animals, action recognition has been studied using these point-light displays, and also animated and recorded videos. This experiment investigated conspecific action recognition in pigeons, with recorded videos of pigeons walking and courting as stimuli.

#### *Importance of recognizing conspecific behavior*

This experiment tested the ability of pigeons to visually discriminate the actions of conspecifics, which is an important skill for pigeons and other animals in the wild so that they can respond appropriately in situations such as agonistic interactions, social foraging, and mate selection. For example, the ability to recognize an aggressive display is essential in avoiding unnecessary agonistic interactions. According to Sapolsky and Ray (1989), wild olive baboons that were better able to differentiate between threatening and neutral conspecific interactions had lower stress hormone concentrations in their blood. Individuals who tend to misinterpret neutral

behavior as threatening would spend more time in an agitated state and be involved in a greater number of aggressive interactions. Birds often communicate territorial behavior using a combination of auditory signals and threat displays such as wing extension and head-forward posture (Hurd & Enquist, 2001). Being able to recognize these conspecific threat displays is an essential skill for birds and other animals.

Birds also use visual signals during courtship. While some birds attract mates through their songs, others rely primarily on visual signals. Some birds show off visual features that make them attractive to females, such as the peacock's elaborate tail. Other birds have courtship rituals consisting of sequences of movements that are usually energetically demanding and species-specific. Male pigeons pursue females by engaging in a series of movements, including puffing out their neck feathers, dragging their tails on the ground, bowing their heads, and turning in a circle, while making a cooing sound and following the female. The female walks away or ignores the male unless she is receptive to mating. This experiment attempts to address which visual cues pigeons use to recognize courtship behavior.

### *Biological motion*

Action recognition in humans is often studied using point-light displays, which depict the movements of a few points of light on key parts of the body, usually the joints. Point-light displays are often used as stimuli in experiments about action recognition because they contain motion cues but not static cues. The movement patterns of living organisms, as often depicted by point-light human or animal models, is known as biological motion. Experiments with point-light displays reveal that humans can easily recognize actions based on motion cues alone (Johansson, 1973).

In fact, perception of biological motion may be a precursor to more advanced social cognition such as understanding the intentions of others and recognizing emotional states. People can detect emotions such as fear, anger, grief, joy, surprise, and disgust from the movements of point-light dancers (Dittrich, Troscianko, Lea & Morgan, 1996). Deficits in biological motion processing are often associated with social difficulties, as seen in individuals with autism spectrum disorders (Kaiser & Shiffrar, 2009).

Of particular interest is whether biological motion perception is as important to the social functioning of animals as it appears to be in people. It has been found that newly hatched chicks, just like newborn humans, preferentially attend to point-light displays depicting biological motion of a walking hen over point-light displays depicting other types of motion (Vallortigara, Regolin, & Marconato, 2005; Simion, Regolin, & Bulf, 2008). This indicates a predisposition towards biological motion, but does not explore whether biological motion perception continues to play a role in social contexts throughout an animal's life.

Very few experiments have studied biological motion categorization in animals using point-light displays. Blake (1993) found that cats were able to discriminate between point-light models of walking cats and point-light displays of non-biological motion with equivalent local motion vectors. Dittrich, Lea, Barrett, and Gurr (1998) investigated the discrimination of conspecific actions in point-light displays and found some of their pigeons were able to discriminate point-light stimuli portraying walking and pecking. However, the pigeons could not transfer full-detail video discriminations to point-light stimuli. These studies indicate that while animals can be trained discriminate categories of point-light displays, more research is necessary in order to explore the relevance of motion cues in recognizing conspecific behavior.

In the current experiment described below, we attempted to isolate motion cues from static cues in the discrimination of behavior in a different way—by conditionally reinforcing trials based on whether the trial consisted of a dynamic video clip or a static frame. The pigeons discriminated between video clips of the behaviors of courtship and walking in two conditions: dynamic and static. In the dynamic condition, videos of pigeons walking were positive, while videos of pigeons in courtship were negative. In the static condition, the assignments were reversed with courtship being positive and walking being negative. Having the pigeons discriminate not only between courtship and walking, but also between moving and static presentations will cause them to attend to the presence or absence of motion and the nature of the behavior being depicted in the video. Using this technique, we should be able to look at the difference in performance in the dynamic and static conditions and from that difference infer the extent to which the pigeons relied on motion and static cues to discriminate courtship from walking.

#### *Action recognition of digital animated models*

This experiment used recorded videos of pigeons walking and courting as stimuli. Using recorded videos instead of animated videos, which have been used in several other studies of action recognition in pigeons, has both advantages and disadvantages. As opposed to digital animated videos, which are easier for experimenters to control, live videos ostensibly provide more realistic representations of behavior.

Other studies have found that pigeons are capable of discriminating action categories of digital animated models. Asen and Cook (2012) found that pigeons learned to discriminate walking from running in a model of a dog and a buck, and then were able to transfer to different animal models. Another study indicates that pigeons can discriminate complex action categories,

martial arts and Indian dance, in digital animated models of humans (Qadri & Cook, 2013). By using conditional reinforcement based on both the action category and state (motion versus static), it was found that pigeons used motion cues independent of static cues. Videos depicting actions contain all of the static cues that are also available in an image. By rewarding pecks to one action category in the motion condition and pecks to the other category in the static condition, the effect of motion cues was isolated by analyzing the difference in performance in the two conditions.

The present experiment used a similar design but different stimuli; in this case, the stimuli were recorded videos of pigeons and the action categories were walking and courting. By using recorded videos of conspecifics as stimuli, we can analyze the discrimination of actions that are biologically relevant.

#### *Using recorded videos as stimuli*

Recorded videos are more difficult than digital animated videos to use as stimuli because recorded videos are more difficult to control. With animated videos experimenters can easily control for variables such as distance, speed, size, color, and position on the screen. The only way to somewhat control for these variables in recorded videos is to record enough videos so that it is possible to select the right combination to balance the variables across different conditions. Even if this is done, each video will still have a combination of features that make it unique. Recorded videos may be easier for pigeons to memorize by rote because there is more information that sets each one apart from the others.

One disadvantage of using digital animated models as stimuli is that pigeons may be less likely to view the models as the objects they represent. According to Asen and Cook (2012), pigeons discriminated digital animated models of other animals walking or running. The pigeons

could not have known what the models represented but they were still able to learn the discrimination. When they watch recorded videos of pigeons it is possible that they perceive the pigeons in the video as real pigeons or as images of pigeons. Pigeons are very detail-oriented, but animated videos tend to obscure the details in favor of the bigger picture. Recorded videos preserve those details but also contain a lot of other information that is irrelevant to the discrimination.

There is some evidence that pigeons treat recorded videos of conspecifics the same way as live conspecifics. Shimizu (1998) studied the behavior of male pigeons in response to recorded videos of females and found that they responded in a similar way to the videos as they did for real females, indicating that visual features alone are enough to elicit courtship displays. By manipulating the videos Shimizu examined which features were critical in eliciting the courtship displays. When the pigeons saw static images, they still responded with courtship displays but the duration of the displays was significantly shorter than for dynamic images. Shimizu concluded that dynamic movement, as well as facial and head features, were important in facilitating the courtship response.

#### *Discriminating actions of conspecifics in pigeons*

Prior studies have revealed that pigeons can learn to discriminate between simple movements, such as flying and pecking, in video scenes of conspecifics. Dittrich and Lea (1993) studied the discrimination between moving and static recorded video images in a go/no-go procedure. They found that pigeons could discriminate between dynamic images and static images of pigeons walking, flying, turning around, and standing still with head movements. The group that was rewarded for pecking moving images learned the discrimination rapidly, while the group that was rewarded after static images did not. This suggests a feature positive effect in

which it is easier for pigeons to respond to the presence of a feature—in this case, motion—than its absence. The pigeons in the motion+ group were able to transfer to novel stimuli depicting a variety of different movements. Dittrich and Lea (1993) established that pigeons are able to perform simple motion/static discriminations of video stimuli. The next studies were the first to use recorded videos of conspecifics as stimuli to explore the discrimination of different motion categories.

Dittrich, Lea, Barret, and Gurr (1998) used a go/no-go procedure to train pigeons to discriminate different motion categories: pecking, walking, flying, head movements, or standing still. In Experiment 1, pigeons discriminated between pecking and non-pecking scenes. Four pigeons were rewarded for pecking at pecking scenes (pecking-positive group), four were rewarded for pecking at non-pecking scenes (pecking-negative group), and four were rewarded for pecking at randomly selected scenes (pseudocategory group). The researchers limited training to 15 sessions with the explanation that discriminations requiring lengthy training are less likely to be biologically significant. While each bird in the pecking-positive group learned the discrimination, only one from the pecking-negative group did. This asymmetry may have been due to a social facilitation effect, in which the pigeons were more likely to peck at the sight of another pigeon pecking, or because the pecking-positive group had one class of positive images whereas the pecking-negative group had several. The pseudocategory group failed to learn the discrimination, suggesting that the successful birds did not memorize the stimuli by rote.

Experiment 2 was similar to Experiment 1 except that the discrimination was between pecking and walking scenes (with a pecking-positive group and a walking-positive group) and with transfer tests to point-light stimuli after 15 sessions of acquisition. Only 3 out of 8 birds demonstrated sustained discrimination, and those 3 birds showed weak transfer to at least some

of the point-light stimuli. The pecking-positive and walking-positive groups did not have significantly different results, indicating that the difference between groups in Experiment 1 was not a result of the social facilitation effect.

Experiment 3 further explored the discrimination of point-light stimuli. Pigeons were trained to discriminate between point-light displays of pigeons walking or pecking and then given transfer tests to full-detail stimuli. The discrimination was clear for 4 out of 8 birds, but with little evidence for transfer to full-detail stimuli.

From this study, it appears that discrimination of movement categories in recorded videos is relatively difficult for pigeons. Some of the birds learned the discrimination in Experiments 1 and 2, suggesting that pigeons are capable of discriminating movement categories from video scenes, but half of them failed to discriminate above chance after 15 sessions of acquisition training. Furthermore, from the results of Experiment 3, it appears that pigeons are able to discriminate movement categories based on motion cues alone as depicted by point-light displays. From this study it is unclear how important the motion cues were for the birds that learned the full-detail discrimination.

Jitsumori, Natori, and Okuyama (1999) further analyzed motion categories and also studied individual recognition. They found that pigeons could discriminate videos of different individual conspecifics performing the same motions. Another group of pigeons discriminated between videos of the same pigeon performing different motions. The stimuli were recorded videos of pigeons key pecking, circling, or pacing. Experiment 2 was of particular relevance to the present study. After learning to discriminate either individuals or motions in Experiment 1, the pigeons were tested for transfer to static scenes from the same videos to determine whether movement was critical in the discrimination. Static scenes decreased the rate of overall

responding, but rates of responding on positive stimuli were significantly higher than for negative stimuli for both groups of pigeons. Both groups successfully transferred the discrimination to static scenes from the same videos, suggesting that the motion of the scenes was not a key factor in the discrimination. These results suggest visual information specific to a particular scene is necessary to discriminate motion categories and individuals, but motion itself is not critical.

The present study builds on prior research in a few ways. First, the behaviors depicted in the videos were more complex. The movements, such as pecking and circling, used in previous studies of motion discrimination were relatively simple. In the present experiment, pigeons discriminated between walking and courtship. Courtship is more complex than pecking because it consists of a sequence of different movements and the precise movements are more variable between individuals and specific situations.

Second, the present study attempts to clarify the role of dynamic cues. Previous studies demonstrate conflicting results regarding the importance of dynamic cues. Jitsumori, Okuyama, and Natori (1999) found that motion was not critical to discriminate conspecific actions, but Shimizu (1998) found that motion was critical in eliciting courtship behavior from male pigeons watching recorded videos of females. The present study attempted to isolate the role of dynamic cues from static cues in the recognition of conspecific behavior. Dynamic videos also contain static cues. Making reinforcement conditional based on whether the stimuli were moving or static should allow us to equate the importance of motion cues with the difference in discrimination performance on the two conditions. The ability to discriminate equally well in both conditions would indicate that the pigeons did not rely on motion cues, while being able to

discriminate behaviors only for moving images would indicate that motion cues play an important role in the categorization of complex behaviors.

Third, little is known about other cues that may influence recognition of conspecific behaviors. In the present study, transfer tests were conducted to examine how blurring the videos, converting them to black and white, and changing the order of frames affected performance. Fourth, this study is similar procedurally to a previously mentioned study that used digital animated models of humans as stimuli. We wanted to explore whether using stimuli that is biologically relevant to pigeons would affect the results.

In this experiment, two pigeons were trained to discriminate between video scenes and static images of pigeons walking and courting in a go/no-go procedure. Static and dynamic cues were isolated by rewarding pecking during dynamic videos of walking pigeons and during static images of courting pigeons. A series of transfer tests were conducted following acquisition in order to assess which cues were being used in the discrimination.

## **Method**

### *Subjects*

Two male pigeons (*Columbia livia*) were included in the study. Both had previous experience with motion and shape discrimination tasks. The pigeons were caged individually in colony rooms on a 12-hour light/dark cycle and maintained at 85% of their free-feeding weight.

### *Materials*

#### Stimuli

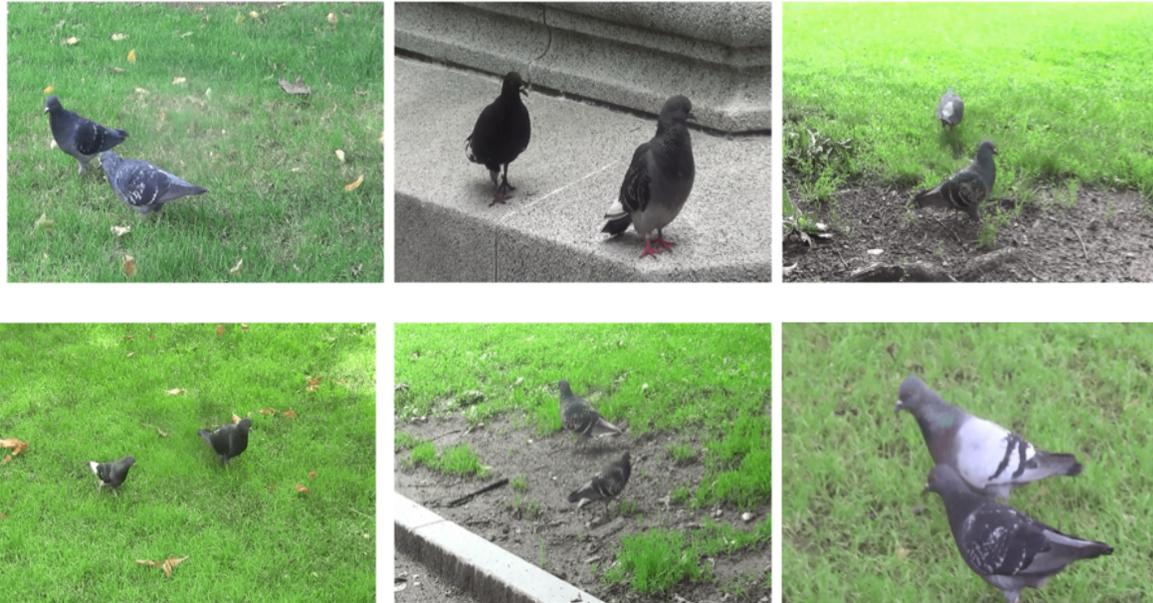
Videos were recorded with a Sony HDR-CX220 camera. All recording took place at the Boston Common in the summer and fall. Pigeons were filmed walking and courting, alone and in

groups. Courtship consisted of the male bowing, cooing, and bobbing his head as he approached a female, and then following her as she walked away (Figure 1). The recordings were transferred to the computer as MTS files and then converted to AVI. They were then edited using VirtualDub to 300 frames of either walking or courtship, without sound, and compressed using Intel Indeo Video 5. Videos were played at a rate of 40 frames per second. Sixteen walking and sixteen courtship videos were selected so that background (grass or concrete) and distance (close or far) were balanced between the two categories of behaviors. However, the number of pigeons in the videos was not balanced—the average number in the courtship videos was 1.88 and the average in the walking videos was 1.44. This was due to the difficulty of recording two, and only two, pigeons walking for 300 consecutive frames, and the difficulty of recording one pigeon courting. In the one pigeon courtship videos, the female was far enough from the male so that only the male pigeon appeared in the video.

A)



B)



**Fig 1.** Examples of static frames depicting courtship (A) and walking (B).

Testing apparatus: Testing took place in a computer-controlled operant chamber that was 38 cm wide x 36 cm deep x 41 cm tall. Stimuli were presented on an LCD monitor (Dell Optiplex 960, resolution of 1024 x 768 pixels, refresh rate of 75 Hertz) that was spaced 11 cm behind a clear touch screen (EZ-170-WAVE-USB, EZscreen, Houston, TX) with an area of 33 x 25 cm in the front panel of the box. The touch screen recorded the number of pecks. A food hopper located centrally beneath the touch screen delivered mixed grain. The houselight in the chamber's ceiling remained on throughout the session except during timeouts.

### *Acquisition*

Acquisition sessions consisted of 96 trials, with 24 trials of each of the condition-behavior combinations: walking-motion, walking-static, courtship-motion, and courtship-static. The order of stimulus presentation was random and different for each session. Stimuli were conditionally reinforced as follows:

Motion	S+	Walking
	S-	Courtship
Static	S+	Courtship
	S-	Walking

**Table 1.** Conditions for reinforcement

Reinforcement occurred on a VI-10 schedule with 2.9 seconds of hopper access for pecks to the positive stimuli. Pecks to the negative stimuli resulted in one half-second of timeout per peck. In order to measure the number of pecks without interruption from the reinforcements, unreinforced probe trials made up 25% of the trials. For each trial, the stimulus was either a randomly selected static frame from a video clip or a video clip itself, starting from a randomly selected frame. Before each stimulus presentation a warning signal, which was a white circle 2.5 cm in diameter, appeared at the center of the screen. The video or image appeared on the monitor for 20 seconds following a peck to the warning signal. With the videos playing at a rate of 40 frames per second and consisting of 300 frames per video, this was enough time for the videos to play through 2.67 times during each stimulus presentation. The next stimulus presentation began automatically if there was 60 seconds without pecks to the warning signal. Forty-five sessions of acquisition were run before the first transfer session.

### *Transfer*

Five types of transfer test were given: novel, in which new videos were shown; reversed, with videos edited to play backwards; blurred, with videos shown at two levels of blur; randomized, with videos edited to play in randomized frame order; and grayscale, with videos presented in monochrome. During each transfer session, transfer trials and baseline trials (with the same stimuli used during acquisition) occurred in random order. The number of baseline

trials was reduced from 96 to 80. Transfer stimuli were presented as unreinforced probe trials. Each type of transfer test was run for four sessions except the novel transfer, which was run for eight. Multiple sessions of baseline/acquisition occurred between each type of transfer test.

### Novel Transfer

Novel videos depicting courtship and walking were presented to determine whether the pigeons could generalize the discrimination to new stimuli. Eight novel videos were selected, with four depicting courtship and four depicting walking. Only four (two walking and two courtship) of the eight novel videos were shown in each novel transfer session, so the pigeons saw each novel video a total of four times over eight sessions. Randomly selected frames from the novel videos were also presented for the static condition.

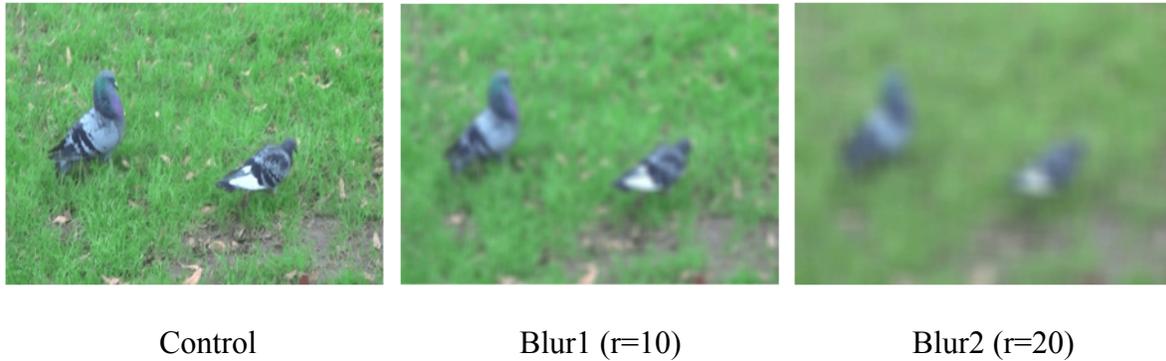
### Reversed Transfer

Reversed transfer tests were conducted to investigate whether the direction of motion was important to the discrimination. Eight videos used during acquisition and baseline trials were selected for use in the other transfer tests. The videos selected were ones to which the pigeons tended to respond correctly (more pecks to walking videos, fewer pecks to courtship videos) so that the inability to transfer the discrimination could be attributed to the manipulation. The forward versions of the reversed videos were also presented as probe trials in order to compare peck rates to the same videos with different manipulations.

### Blurred Transfer

Blurred videos were created using the box blur filter in VirtualDub (Figure 2). Two versions of four of the transfer videos were created, one with the radius set to 10 (slightly blurred) and one with the radius set to 20 (more blurred). In each blurred transfer session, the two blurred

versions as well as the unaltered version were presented as probe trials and were randomly mixed in with baseline trials. Transfer trials occurred in the motion and static conditions.



**Fig. 2** Example of a static frame and the two corresponding blurred versions.

### Randomized Transfer

To assess whether the pigeons relied on coherent motion cues and to control for number of frames, the frames from each transfer video were presented in randomized order at the same frame rate of the videos in the motion condition. The same eight videos used in the reversed transfer test were used in this test.

### Grayscale Transfer

This test was run to investigate whether the pigeons memorized the stimuli based on color differences. Four of the transfer videos were converted to grayscale using VirtualDub (Figure 3).

Transfer test trials were given in the motion and static conditions.



**Fig. 3.** Example of a static frame and its corresponding manipulated image.

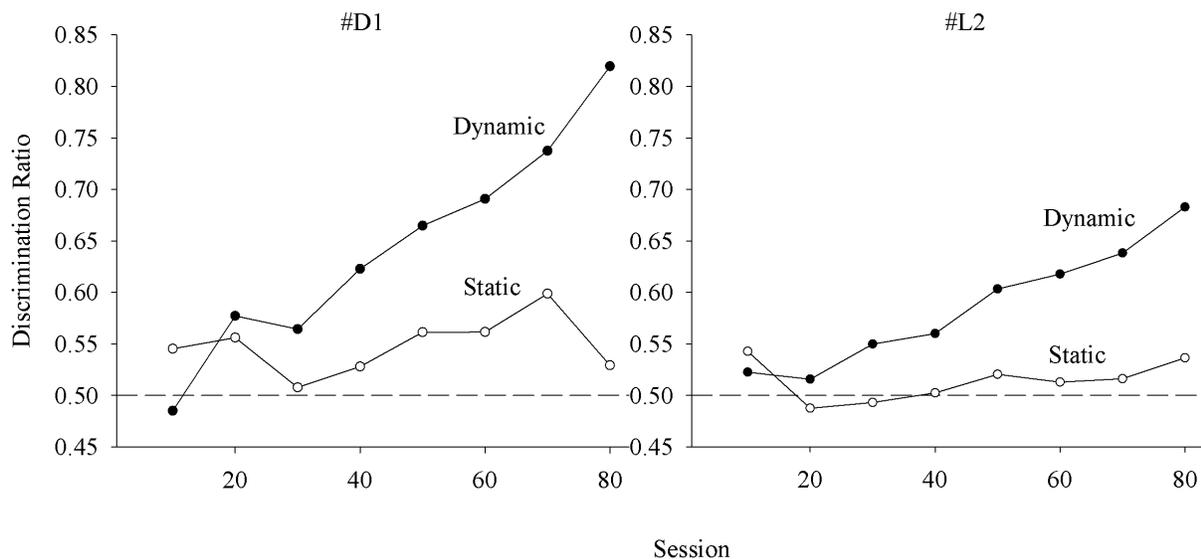
### Data Analysis

Discrimination ratios (DR=pecks to S<sup>+</sup> / total pecks) were calculated using the number of pecks during the final 10 seconds of each trial. The number of pecks during the second half of the trial were used instead of the number of pecks during the whole trial because when the stimulus first appears on the screen the default behavior is to peck. Using only the second half of the trial is therefore a more accurate reflection of discrimination learning. Statistical tests were conducted using SPSS. An alpha level of .05 was used to judge significance.

## Results

### Acquisition

Both birds learned to discriminate walking videos from courtship videos in both conditions, but they learned the dynamic discrimination faster and better than the static discrimination. Pigeon #D1 required 38 sessions to reach a criterion DR of .65 for two consecutive sessions in the dynamic condition. Pigeon #L2 required 66 sessions. Neither reached this level of performance in 80 sessions in the static condition. Figure 4 shows the change in discrimination performance during the first 80 sessions.



**Fig. 4.** Mean discrimination ratios during the first 80 sessions for #D1, left, and #L2, right. The horizontal line at .50 represents chance performance.

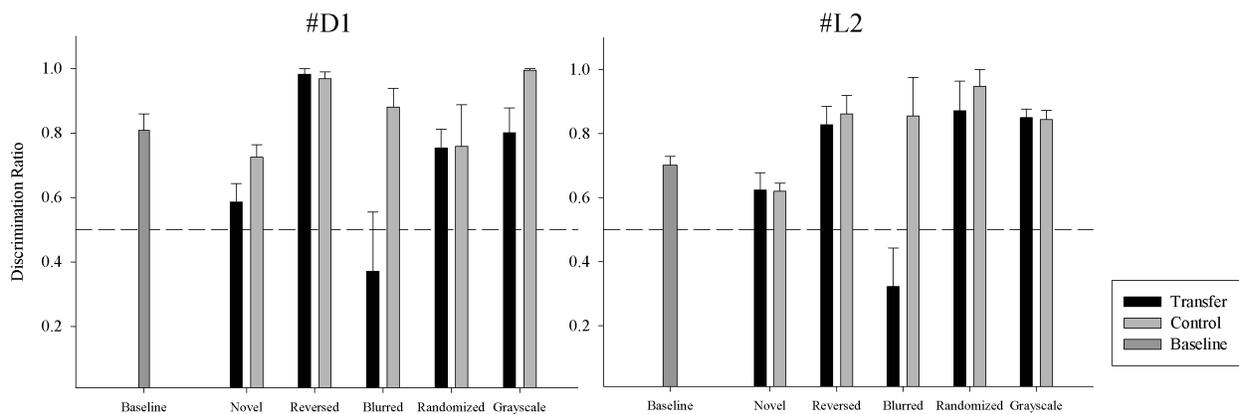
A repeated measures ANOVA analyzing DRs with two within-subject factors—session (eight levels each representing groups of ten sessions) and condition (dynamic or static)—revealed a main effect for session,  $F(7,7)=7.13$ ,  $p=.009$ , indicating that both birds improved their performance over time. No significant main effect was found for condition,  $F(1,1)=47.99$ ,  $p=.091$ . There was, however, a significant interaction between condition and session,  $F(7,7)=8.13$ ,  $p=.006$ . This interaction shows that performance in the dynamic condition improved more throughout the sessions than performance in the static condition.

### *Transfer*

To determine whether the birds were discriminating before the transfer sessions began, a one-sample t-test using the DRs from the ten sessions before the first transfer test (sessions 36-45) was conducted. Even though discrimination ratios continued to increase beyond this point, transfer tests started during session 46. The rationale for starting the transfer sessions while performance was still improving was because memorization of the stimuli becomes more likely with more training. We wanted the pigeons to categorize stimuli instead of memorizing them. Both birds discriminated above chance in both conditions. For #D1, the mean DR in the motion condition was .63, ( $SD=.039$ ),  $t(9)=10.2$ ,  $p<.001$ ,  $d=3.24$ , and the mean in the static condition was .56 ( $SD=.061$ ),  $t(9)=2.9$ ,  $p=.018$ ,  $d=.916$ . For #L2, the mean DR in the motion condition was .58 ( $SD=.0453$ ),  $t(9)=5.673$ ,  $p<.001$ ,  $d=1.80$ , and the mean DR in the static condition was .52,  $t(9)=3.026$ ,  $p<.001$ ,  $d=.953$ .

Transfer test results indicate that temporal order of frames, as well as color, had no effect on the discrimination and that static features were more critical. These results are summarized in Figure 5. Mean DRs were calculated for each type of transfer test, and then a one-sample t-test was conducted to determine whether each pigeon discriminated the transfer videos significantly above chance. On transfer test types that were found to be above chance, a paired-samples t-test was conducted to determine whether control performance differed from transfer performance. A significant difference on the paired-samples t-test would indicate that pigeons did not transfer the discrimination.

The pigeons did not show evidence of transfer to stimuli in the static condition. Because of this, only the transfers in the motion condition are included in the data analyses. Static DRs before the start of the first transfer test were .56 and .52, as noted previously. To find significant transfer in the static condition at these DRs with a power of .80, ten sessions of each transfer type for pigeon #D1 and twelve for pigeon #L2 would have been required. Therefore, we cannot conclude that the pigeons were unable to discriminate static transfer stimuli.



**Fig. 5.** Mean discrimination ratios on transfer and control trials for pigeon #D1, left, and pigeon

#L2, right. The baseline bar represents the average baseline performance for all transfer sessions.

### Novel Transfer

Pigeon #L2 demonstrated weak transfer to novel videos while #D1 did not. Pigeon #L2 discriminated marginally above chance on novel videos,  $t(7)=2.34$ ,  $p=.052$ ,  $d=.827$ . His performance on baseline trials ( $M=.620$ ,  $SD=.072$ ) was not significantly different from his performance on transfer trials ( $M=.624$ ,  $SD=.150$ ),  $t(7)=.086$ ,  $p>.05$ .

### Reversed Transfer

Both pigeons transferred the discrimination to videos played in reverse. Pigeon #D1 discriminated reversed videos above chance,  $t(3)=26.50$ ,  $p<.001$ ,  $d=13.2$ , and there was no significant difference between control and transfer DRs. Pigeon #L2 also discriminated reversed videos above chance,  $t(3)=5.65$ ,  $p=.011$ ,  $d=2.82$ , with no significant difference between control and transfer DRs.

### Blurred Transfer

Neither pigeon attained a mean DR significantly above .5 on blurred videos.

### Randomized Transfer

Both pigeons transferred the discrimination to videos with frames in randomized order. Pigeon #D1's mean DR on randomized videos was significantly above chance,  $t(3)=4.31$ ,  $p=.023$ ,  $d=2.16$ , and there was no difference between control and transfer DRs. Pigeon #L2 also discriminated randomized videos above chance,  $t(3)=12.10$ ,  $p=.001$ ,  $d=6.05$ , with no difference between control and transfer DRs.

### Grayscale Transfer

Both pigeons transferred the discrimination to monochromatic videos. Pigeon #D1's performance was above chance for grayscale videos,  $t(3)=3.905$ ,  $p=.030$ ,  $d=1.95$ . Pigeon #L2 also discriminated randomized videos,  $t(3)=4.022$ ,  $p=.028$ ,  $d=2.008$ . There was no significant difference in performance between control and transfer trials for either bird.

### *Static frame coding*

Frames from courtship videos in the static condition were analyzed for peck rate. Some frames depicted courtship behavior more obviously than others. For example, transitions between different courtship behaviors, moments where the male pigeon paused, and brief segments when the male was following the female without displaying, were all moments in which a static frame from a courtship video might look like walking. If the subjects were classifying stimuli based on the categories of courtship and walking using static cues, they should respond more correctly on frames that more obviously depicted one behavior over the other. Courtship videos were analyzed because they contained a greater range of discrete behaviors than walking videos. For each courtship video, the frames were grouped by 10 and then the three groups of frames with the most pecks were compared to the three groups of frames with the fewest pecks, separately for each bird. Each set of frames was analyzed to determine whether it contained bowing, tail-dragging, and and/or neck extension (Figure 6).



**Fig. 6.** Example frames depicting bowing (left), tail-dragging (middle), and neck extension (right)

Since courtship was the positive behavior in the static condition, the subjects should have pecked more at frames that depict bowing, tail-dragging, and neck extension if they were using these features to categorize courtship behavior. It was found that there was no significant difference in the number of courtship display behaviors in the frames with the most pecks and the frames with the fewest pecks, as reported in Table 2. There was also no significant difference in the number of frames containing no discrete behaviors.

Bird	Behavior	Number of appearances in the frames with the most pecks	Number of appearances in the frames with the fewest pecks
#D1	Bow	19	15
	Tail drag	15	17
	Neck extension	15	15
#L2	Bow	20	19
	Tail drag	15	17
	Neck extension	17	16

**Table 2.** Comparison between the number of different courtship behaviors depicted in the static frames with the highest number of pecks and lowest number of pecks.

### General Discussion

The major findings of this experiment were that performance on the motion discrimination was better than performance on the static discrimination, that temporal order of frames was not critical as indicated by the results of the randomized and reversed transfer, and that form features were more critical as their blurring eliminated performance.

While it is consistent with prior research that dynamic stimuli were discriminated better than static stimuli, these results suggest that the reason for this dynamic superiority effect was not due to motion cues. The pigeons were still able to discriminate videos when the frames were presented in randomized order. In other studies of motion discrimination, randomizing the frame

order of the dynamic stimuli decreased performance. Cook, Shaw, & Blaisdell (2001) found that pigeons learned to discriminate passing through a computer-generated 3D object with a central opening and going around it, from the perspective of the camera. When the frame order was randomized, performance declined. In another study, Cook and Roberts (2007) trained one group of pigeons to discriminate the around and through videos, and another group to discriminate the same videos with randomized frame order. The group that was trained with coherent videos learned to discriminate better than the randomized group. Additionally, in the discrimination of martial arts and Indian dance, pigeons could no longer discriminate when the frame order was randomized (Qadri & Cook, 2013). These experiments indicate that pigeons use coherent motion cues to discriminate movements of computer-generated models.

In the present experiment, it was found that randomizing the frame order did not affect the discrimination. This suggests that motion cues are not critical in the discrimination of recorded videos as they are in computer-generated models. Jitsumori, Natori, and Okuyama (1999) also demonstrated that motion cues were not important in the discrimination of videos of conspecific behavior. While their study did not include a randomized frame transfer test, they found that the pigeons transferred to videos played in reverse, and that they transferred the dynamic discrimination they learned to static frames. The researchers concluded that information that is scene-specific is necessary for pigeons to discriminate, regardless of whether that information is dynamic or static.

The results of the present experiment support this conclusion. Furthermore, our results indicate that while static information specific to a particular video may have allowed the subjects to transfer to the same scenes with altered frame sequences, information that was category-specific was unimportant. In other words, the pigeons may have memorized the individual

stimuli instead of classifying them according to the categories of walking and courtship.

Evidence that static category-specific information was unimportant comes from analyzing the number of pecks to frames in the static condition. The number of pecks to static courtship frames (which were positive in the static condition) varied by frame. The courtship videos contained brief segments in which the male was not displaying and the scene looked like walking. If the pigeons tended to peck more at frames that clearly depicted courtship displays, it would indicate that they were using static cues to discriminate the action categories. This was not the case, and the courtship frames with higher peck rates were no more likely than images with lower peck rates to include courtship postures.

The pigeons also had difficulty generalizing to novel videos, which supports the implication that they used rote memorization of the stimuli during training. Pigeon #L2 demonstrated weak transfer to novel videos, while the other bird did not. Pigeon #L2 may have been using static cues such as distance between pigeons or their positions to generalize. More subjects are needed to clarify whether transfer to novel stimuli in this experiment is common or rare.

The pigeons may have learned the dynamic discrimination better than the static as a result of the additional static cues available in trials in the dynamic condition—while stimuli in the dynamic condition consisted of 300 frames, stimuli in the static condition consisted of just one. Multiple frames provided more information than any one single frame used in static trials. This may explain why the birds were able to perform so well on the randomized transfer tests.

Compared to videos of digital animated models, the recorded videos used in this experiment were much more complex because they contained more information that was irrelevant to the discrimination, such as backgrounds and background motion. Categorization

becomes more difficult for pigeons as the amount of non-informative context increases (Donis, Chase, & Heinemann, 2005). Therefore, it might have been easier for the pigeons to remember which of the 32 videos were positive and which were negative, and reverse these assignments in the static condition, than it was for them to categorize conspecific actions.

The failure to recognize conspecific actions in recorded videos may have occurred as a result of the subjects not perceiving conspecifics in the videos. Pigeons likely do not see exactly what we see when they view a recorded video on a computer monitor because video equipment is optimized for human vision. Bird vision differs from primate vision in a few ways that would affect how they perceive images on a screen. The first issue is color reproduction. Colors are reproduced on a computer or television screen to match how humans see colors in real life. Humans have three types of cone cells in their retinas for detecting red, green, and blue light. Pigeons have an additional set of cone cells for detecting ultraviolet light. From a pigeon's perspective, the video stimuli were missing an entire dimension of color.

Second, pigeons may perceive the motion in videos differently. Pigeons have a higher flicker fusion threshold, which is the rate at which a flickering beam of light is perceived as continuous. On an LCD screen, which is what was used in this experiment, the high refresh rate of the backlight would prevent them from seeing a flickering strobe-light effect. However, the information on the screen still refreshed at a rate lower than the flicker fusion threshold of pigeons, so it is possible that the motion appeared less smooth to them than it was for us. Another relevant concept is the minimum rate at which individuals perceive motion from successive static images. For humans, this is 15-20 frames per second, and in pigeons it is known to be higher. This experiment, like others before it that did show evidence of pigeons' use of coherent motion cues, utilized videos played at 40 fps. Differences in how pigeons

perceive motion in videos may have affected their use of motion cues in discriminating recorded videos.

Taking these visual perception differences into account, are recorded videos realistic enough to substitute for the real object in experiments with birds? Some studies have indicated that they are. Shimizu (1998) found that male pigeons responded to videos of female pigeons with courtship displays the same way they responded to live female pigeons, suggesting that videos can substitute for a real conspecific. In a study with chickens, Evans and Marler (1991) reported that alarm-calling occurred at a similar level in the presence of videos of other chickens as it did in the presence of live conspecifics. However, both of these studies were conducted using naïve subjects, with no previous screen experience. It is possible that repeated exposure would cause them to become habituated to the screen and to stop responding as if the images were real. Also, the pigeons in the first study were first presented with live conspecifics behind a window, which was then replaced by a screen. The subjects may not have responded the same way to the videos if they had not been primed first with live conspecifics.

The subjects in the present experiment did not respond to the videos with courtship displays, which provides evidence that in this experiment the pigeons did not see conspecifics in the videos or that they learned from their previous screen experience that images are not real. This lack of correspondence between the video images and live conspecifics may have affected the way the subjects approached the discrimination.

While the pigeons in this experiment were able to discriminate the video stimuli in the motion and static conditions, the results suggest that they were not able to categorize based on the conspecific actions depicted in the videos. It is unclear whether this is occurred as a result of

the irrelevant details present in recorded videos, or whether it was an issue with video-object correspondence.

### *Future Directions*

In the future, it would be interesting to repeat this experiment using socially experienced but experimentally inexperienced subjects. The pigeons used in this experiment had no experience interacting with conspecifics, although they are able to see and hear the other male pigeons in the colony room. Perhaps these pigeons would have difficulty recognizing courtship behavior in the wild as well. In addition, using experimentally naïve subjects may reduce possible correspondence problems.

To prevent the pigeons from using irrelevant background information to remember which stimuli were positive and which were negative, video-editing software could be used to remove the backgrounds. Presenting the pigeons moving on a solid background and would significantly reduce the amount of non-informative context and may facilitate the categorization of actions.

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