Cognitive Mechanisms Used by Pigeons to Determine Behavioral Action

An Honor Thesis for the Department of Psychology

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Abstract

The recognition of others' behavior is vital for all animal species, including the highly mobile pigeon (*Columba livia*). Previous research shows that pigeons can discriminate behaviors using single static poses and smooth motion pose sequences. We investigated whether pigeons use perceptual or mnemonic mechanisms during this discrimination. Three pigeons were tested using a go no-go task in which the birds were presented with either single poses or multiple stationary poses of two distinct behaviors. After determining that the birds were using momentarily available perceptual cues, we started training to promote the use of mnemonic mechanisms. After this training, perceptual features were still found to be vital for the pigeons' discrimination, suggesting that these features are more accessible than the memory of recently viewed poses. Comparisons to theories of action recognition in humans will be discussed.

Introduction

The ability for animals to recognize actions in both conspecifics and non-species is a skill necessary for survival. This is especially important for animals to successfully detect courtship, foraging, and predator stalking behavior. Socially complex animals like humans also rely on this ability to recognize specific actions so that they can respond appropriately.

The detection of these actions is heavily facilitated by the brain's visual system. The recognition of motion in living things is specifically accomplished with multiple neuronal pathways. To recognize actions, neurons that are part of a form recognition pathway handle shape features of an action while a motion pathway neurons process the optic flow patterns (Geise & Poggio, 2003). Acting, full bodied models activate both pathways which allows for recognition of a variety of actions. In stimuli that only retain motion features, as is the case with point light displays, the motion pathway can still function independently to recognize actions without the use of form cues (Johansson, 1973). This indicates that motion itself can serve as a salient cue for behavior recognition on its own.

Studies have shown that pigeons are able to make discriminations based on these motion cues alone. Cook, Beale, and Koban (2011) showed that pigeons learned to discriminate between objects rotating at fast vs. slow speeds. Their ability to maintain this discrimination across 40 different objects indicates that the birds were making their discrimination without the use of object specific features. The pigeons were then introduced to new rates of rotation to which they responded systematically, suggesting that not only was object rotation speed adequate for discrimination, but that they could also apply this discrimination to additional rotational speeds as they had acquired a generalized idea of speed.

Motion cues can be categorized as either local or global in nature, depending on how

much of the stimulus is processed by the viewer. In the context of action recognition, local features describe individual parts of an actor partaking in a behavior, whereas global features are inherent to the entire actor. Research on whether pigeons prefer the use of local or global cues in action discrimination tasks have shown mixed results as they have shown preference for both cue types in past research. A study performed by Troje and Aust (2013) looked at whether pigeons would prefer to use local or global features when discriminating videos of walkers. They found that while most birds seemed to prefer the use of local features to make their discrimination, two of the birds showed that they were clearly using global features. These results suggest that pigeons most likely can use both local and global features but show a preference for one over the other.

Although perception of motion alone can yield adequate discrimination, the use of stored visual information in short term memory systems can also facilitate solving such a task. Wright et al. (2010) showed that pigeons learned a change detection task in which an array of circles either changed or remained constant after a delay. The birds not only learned to peck at changed conditions but showed transfer of this discrimination to circles of novel colors. One way the pigeons could have learned this was by utilizing attentional capture, where the change in stimuli separated by short enough delays is brief enough to be captured by the visual system. The second part of this study sought to determine if this discrimination was solely derived from the attentional capture from the abrupt color changes. However, the results showed that pigeons could still perform significantly above chance even on inter-stimulus delays of up to 6,400ms. This length of time surpasses the capacity for attentional capture suggesting that the birds were retaining information about the previous stimuli in their short term memory.

A similar change detection study was done by Hagmann and Cook (2011) where pigeons

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were tested with squares that changed in brightness at various rates. The experiment was initially performed with the constant, no change condition designated as the negatively reinforced condition. In go/no-go procedures however, negative trials tend to reveal discrimination trends more than positive trials. This is because pigeons tend to peck at all stimuli and then suppress this pecking at negative trials. This suggests that the birds showed their ability to detect constancy, rather than change, in the first set up.

With a new set of pigeons, the previous conditions were reversed so that the changing condition was assigned as the negative trial type. Regardless of experimental setup, the pigeons still showed the ability to detect changes in brightness dependent on rates of change. It is thought that pigeons can perform change detection tasks like these through use of both perception and working memory mechanisms. At faster rates of change, the visual system's ability to detect motion is adequate for this discrimination. At slower rates of change, however, it then becomes necessary to employ short term memory systems.

Behavioral sequences provide an excellent area of study to further investigate the interplay of these motion cues and memory mechanisms during action recognition. Behaviors include not only information in the form of specific poses but also in the form of optic flow patterns that result from the changes in poses (Giese & Poggio, 2003). Many studies that have aimed to look at the discrimination of action behaviors in pigeons have used 'walking' and 'running' as test behaviors because they have been shown to be naturally important actions (Malt et al, 2008).

Mui et al (2007) found that both pigeons and budgerigars could discriminate between videos of a person walking a dog forwards and backward and showed the ability to transfer this discrimination to videos in which the person was facing a different direction. Their success in

this task indicates that birds can detect the direction of actions using information about the sequences of poses.

Building off these prior studies, Asen and Cook (2012) examined pigeons' ability to discriminate between walking and running animal models of a dog and buck. The birds were quickly able to learn the discrimination and apply this to novel animal models. Given the drastic differences between the models (i.e., elephant versus human), the ability for the pigeons to maintain discrimination suggests that their choice was independent of the species-specific differences in gait and physical appearance. Multiple transfer tests were conducted with these stimuli to determine what information was and was not necessary for discrimination. Inverting the stimuli such that the animals' legs pointed upward disrupted the discrimination, as did randomization of the frames. Static presentations of the models also did not yield discrimination, but both reversing direction of travel and speed of presentation had no impact on discrimination. These results not only suggest that sequencing of frames is vital for discrimination, but also that pigeons seem to rely on global cues of motion that were disrupted in the stimulus inversion case.

The visual basis of such action discriminations was investigated thoroughly by Qadri, Asen, and Cook (2014) using the same walking and running baseline models used in the prior experiment. This study focused on the visual aspects of the stimuli that allowed for discrimination by incorporating new versions of the walking/running models. One of the new models used were point light display (PLD) models; these models have dots of light placed at each key joint but without any connecting features between. Although humans have shown ability to quickly recognize this series of dots as motion, birds have been less successful. Pigeons did not show ability to transfer baseline discrimination of full walking/running models to point light displays in standard, inverted, scrambled, or randomized frame conditions. A study done by

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Dittrich et al (1998) with pigeons and PLD's showed similar results, suggesting that pigeons do not process these types of videos the same as integrated forms of motion. These point light display studies support the idea that pigeons not only have issue integrating parts into a whole, but that in these cases they preferentially attend to local cues over global ones.

Various types of form information were also tested with the pigeons by Asen, Qadri, and Cook in their experiment. The pigeons showed the ability to discriminate both silhouette versions (entire buck was the same color) and contour versions (only outline present) of the previously described buck walking/running stimuli. These discriminations were both disrupted by rotation of the stimulus however. Since rotating the stimuli retains local features of motion, these results suggest that the pigeons were not relying on local cues given that they were present in both the control and test condition. Vertical motion was also found to not be crucial for discrimination as inversion of the stimuli (such that the buck's head faced downwards) also disrupted discrimination, despite retaining all the same up-down motion from before. Finally, frame randomization continued to prove difficult for the pigeons to discriminate, indicating that coherent motion is necessary for the birds to discern the stimuli.

Moving beyond simply testing with walking and running stimuli, recent experiments by Qadri, Sayde, and Cook (2014) have examined pigeons' ability to discriminate complex human behaviors. In this study, pigeons were tested with a human model that performed either an Indian Dance or martial arts behaviors which were both presented as either dynamic or static stimuli. Pigeons showed the ability not only to discriminate between these two behaviors, but showed a better discrimination with dynamic videos than with static presentations of the same behavior, a phenomenon dubbed the 'dynamic superiority effect' by the researchers. This effect can be explained by differences that exist between the two conditions. Not only do pigeons attend more

to stimuli in motion, but dynamic videos inherently contain more information for pigeons to process. In addition, frames from each behavior condition do not necessarily carry the same amount of discriminable information meaning that the exact pose seen in the static condition is much more unlikely to yield discrimination than if various poses are seen in succession.

Further experiments with the same human behavior stimuli focused on the stimulus cues that allowed for discrimination. Qadri and Cook (2017) hypothesized that both pigeons and humans would use a combination of both pose information derived from static presentations as well as motion cues from dynamic to make their discriminations. This hypothesis was tested by placing these pose and motion cues in competition with one another so that accurate recognition of both were required for successful discrimination. Both humans and pigeons were successful with these discriminations and it is believed that both species use a combination of these cues to make their decision. As seen in the prior experiment, both species showed better discrimination with dynamic stimuli versus static stimuli.

In the first experiment, the memory mechanisms used by pigeons for action recognition were examined by testing pigeons with new pose duration stimuli. New baseline training attempted to force pigeons to utilize memory to make their discrimination. In the second experiment, additional features of the stimuli were also tested to determine their contribution to the pigeons' discrimination.

Experiment 1

Introduction

In past studies, pigeons have shown that they can discriminate between different types of temporally extended and non-repetitive stimuli (Qadri & Cook, 2014). These studies showed that pigeons were not only able to discriminate between both behaviors, but also between full motion sequences and single frames taken from these same sequences. The specific cognitive mechanisms used to determine action or inaction in both behaviors is unknown, however. One theory is that pigeons use short term memory storage of prior stimuli information that can be compared against present stimuli against to determine any change between the two. The current experiment aims to 1) measure their default limits for detecting change, 2) force pigeons to use memory to make discriminations, and 3) attempts to find a limit for their short-term memory of visual stimuli.

To test this memory capacity, the same human stimuli used by Qadri and Cook (2014) were altered to force the pigeons into a memory based discrimination state. The same human models were recreated so that they now appeared to hold a pose before switching to holding another new pose. This setup resulted in a series of poses that were each seen for a certain amount of time. It is important to note that 3D pose motion was present, but motion from the moving camera was. The length of time in which the actor holds his pose will be referred to as the pose duration.

The original acting and stationary conditions can be viewed as the two endpoints of this condition in which the model holds his pose. In stationary presentations where the pose does not change, pose duration is equal to 600 frames which is the length of the entire trial. For acting

presentations, pose duration is equal to 1 frame since the pose changes every frame. Pose duration values in between values of 1 and 600 therefore result in stimuli that hold a pose for certain duration before moving on to the next one.

In this experiment, pigeons were first tested and then trained on the discrimination of new pose duration values between 1 and 600 frames. The goal of this experiment was to force pigeons to utilize memory by forcing them to compare mental representations of prior poses to current ones. The correct discrimination of these stimuli require that the birds are aware that the poses have changed from previous poses using visual short term memory.

Methods

Participants

3 male pigeons (*Columba livia*) with prior experience in behavior discrimination were tested. The pigeons were housed and tested at 80-85% of their free feeding weights, with unlimited access to grit and water in their home cage.

Apparatus

A touchscreen equipped (EZ-170-WAVE-USB) operant chamber was used to present video stimuli and record peck responses. Stimuli were displayed on a LCD computer monitor (NEC LCD 1525X; 1024 x 768, 60 Hz refresh rate) that was placed 8 cm behind the touchscreen. A central food hopper located in the center below the touchscreen administered a mixed grain reward to the birds. A 28 V houselight in the chamber ceiling was constantly illuminated, except during timeouts.

Stimuli

A human model (motioncapturesociety.com) that acted in either an "Indian Dance" or "Martial Arts" action sequence was used as the stimuli for this experiment. The frames of the sequences were rendered to PNG using digital software (Poser 8, Smith Micro) and then stitched together to create AVI videos using MATLAB (MathWorks) and Virtual Dub (GNU, General Public License) with the Cinepak codec. Videos for both behavior classes were developed using four different sequences of poses.

The perspective camera was also in constant motion for both static and dynamic videos. This addition was implemented given that past studies showed that the birds displayed a clear dynamic superiority effect in their discriminations (Qadri & Cook, 2017). This refers to the increased performance shown by the pigeons on the dynamic stimuli versus stationary. In addition, motion inherently serves to capture the birds' attention compared to stationary stimuli. To control for this, a camera was implemented that constantly travelled around the acting human model in a specific path. The addition of a dynamic camera perspective results in motion for all conditions. Since all videos then technically contain motion, the videos in which the actor moves through the behavior will be referred to as the "acting" condition and the videos in which only one pose of the actor is shown will be referred to as "stationary." These terms are more accurate than the use of dynamic and static as they now refer solely to the human model's behavior and not the overall motion of the video. An example of an acting and stationary condition both with a moving camera following the same path can be seen in figure 1.
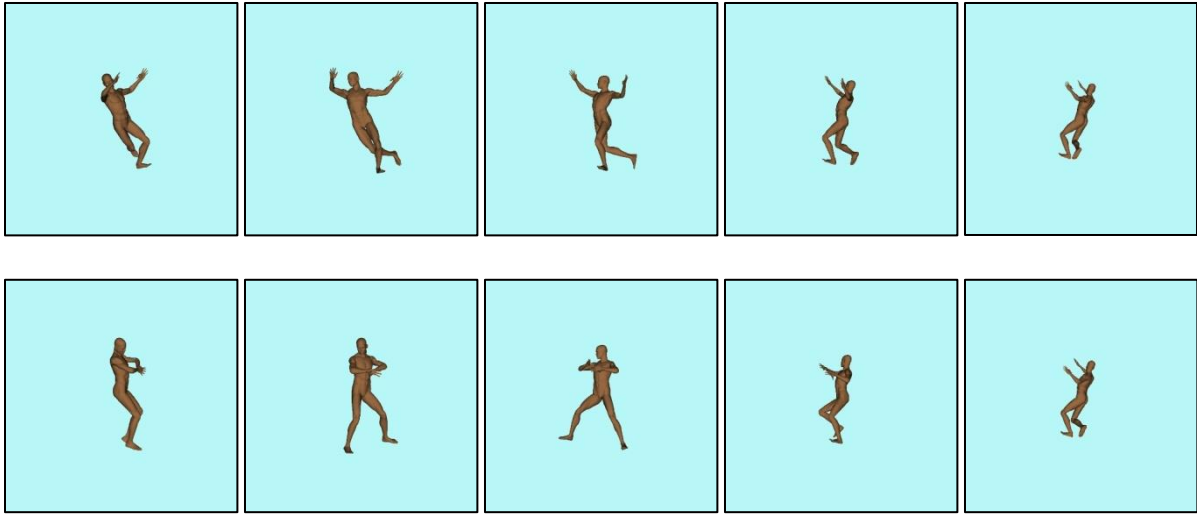
Figure 1. Sequence of poses taken from Indian dance videos with a moving camera. Pictured top is the stationary condition and pictured bottom is the acting condition.

Videos where the human model holds its poses for various amounts of time were rendered and produced using this constantly moving camera perspective. In these "pose duration" videos, the pose remained the same for a specified duration, resulting in a stimulus that appeared to "hold" his pose rather than move fluidly from pose to pose without interruption. These videos are referred to as "pose duration" videos, where the numeral accompanying the pose duration refers to the length of the pose in terms of frames (each frame is displayed for 30 milliseconds). The baseline videos can also be described with this nomenclature; the original dynamic videos have a pose duration of 1 and stationary videos have a pose duration of 600 frames. Given these limits, all new videos generated had a pose duration between 1 and 600 frames.

Procedure

The pigeons had been trained previously on the conditional discrimination in a go/no-go procedure of two action sequences, Indian Dance and Martial Arts. For all three birds, the

'Indian Dance' acting condition and the 'Martial Arts' stationary condition were designated as S+ trials. Pecks to these S+ trials were reinforced with access to mixed grain for 4500, 3700, and 4000ms for birds A1, W1, and A2 respectively. Indian Dance stationary and Martial Arts acting trials were assigned as the S- condition, where pecks to the stimuli would result in a timeout. These baseline conditions remained the same through the experiment.

Trials were initiated by a peck to a 2.5 cm white circular ready signal which was then replaced by a video for 20s. Reinforcements were delivered on a variable interval schedule after the first peck after a random interval of time. Both trial types were then followed by a 3-s inter stimulus interval delay before the presentation of the next ready signal. To obtain peck rates for S+ trials that were not disturbed by the birds' time accessing the hopper, some trials in each session were designated as "probe" trials in which the birds were not reinforced for pecks at S+ stimuli. These probe trials were used for the S+ data during data analysis.

Initial Transfer: For the first test, pigeons were presented with dynamic, static, and new pose duration videos for 4 sessions. The novel pose duration videos were all tested as probe trials in which no reinforcement or punishment was administered. Pose durations of 5, 20, and 120 frames were the first values to be tested alongside baseline videos. In each session, pigeons completed 124 trials (62 S+ trials and 62 S- trials) with 14 probe trials present in each session.

We then tested 6, 8, 10, 12, and 15 frames as the next set of pose durations. In each session, the pigeons completed 136 videos (68 S+ trials, 68 S- trials), and 18 probes were used in these sessions due to the increased number of pose duration values tested. Following this test, the total amount of movement in the videos was controlled for using absolute difference values between subsequent frames. This was accomplished by examining the 'total pixel change' between each frame of the videos for both behaviors. The camera moving around the actor could

move in several different pathways which resulted in various amounts of absolute motion for different paths. The total change was then controlled for by only using those videos in which this measure was greater for martial arts than Indian dance.

One final test was then run with 3, 4, 5, 6, and 8 pose duration videos to try and determine the point in which pigeons switch their responses. This point represents the perceptual midpoint between both behavior and motion type (acting and stationary) differences. For four sessions, the birds completed 132 trials (66 S+ trials, 66 S- trials) with 18 positive trials being probe trials.

Extended Training: Once a crossover point was determined to naturally reside approximately between pose durations 3 and 6, the goal was to begin training the pigeons with these stimuli. This resulted in a new baseline condition in which the dynamic stimuli were replaced with pose duration stimuli. The static condition remained unaffected.

In these training sessions, the pigeons were presented with 128 trials; 64 S+ and 64 S- trials. The birds were trained until they showed adequate discrimination based on peck rate differences between negative and positive probe trials.

Once discrimination was reached, transfer sessions were administered with new pose duration values to determine if training had any effect on the crossover point. In these sessions, 136 trials were shown to the birds with 68 S+ trials and 68 S- trials, including 20 probe trials. The birds were tested with these transfer stimuli over the course of 4 sessions to test all iterations of pose duration and pose sequences for each behavior. This process of training and then testing transfer values was repeated until the training discrimination deteriorated. The pigeons started on the same training values but all eventually diverged from one another due to differences in performance. Bird A1 was trained at pose durations of 5, 12, 30, 60 and 75; bird W1 was trained

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at pose durations of 5, 12, 30, 50, 60 and 75; and bird A2 was trained at pose durations of 5, 12, 15, 40, 60 and 75.

Results

The pigeons were previously trained on a conditional discrimination in which they had to accurately discriminate both behavior and motion type. All three birds yielded a significant difference in responses to both behavior and motion: Bird A1 $t(9)=15.45$, $p<.001$, Bird W1 $t(9)=28.195$, $p<.001$, and bird A2 $t(9)=9.997$, $p<.001$.
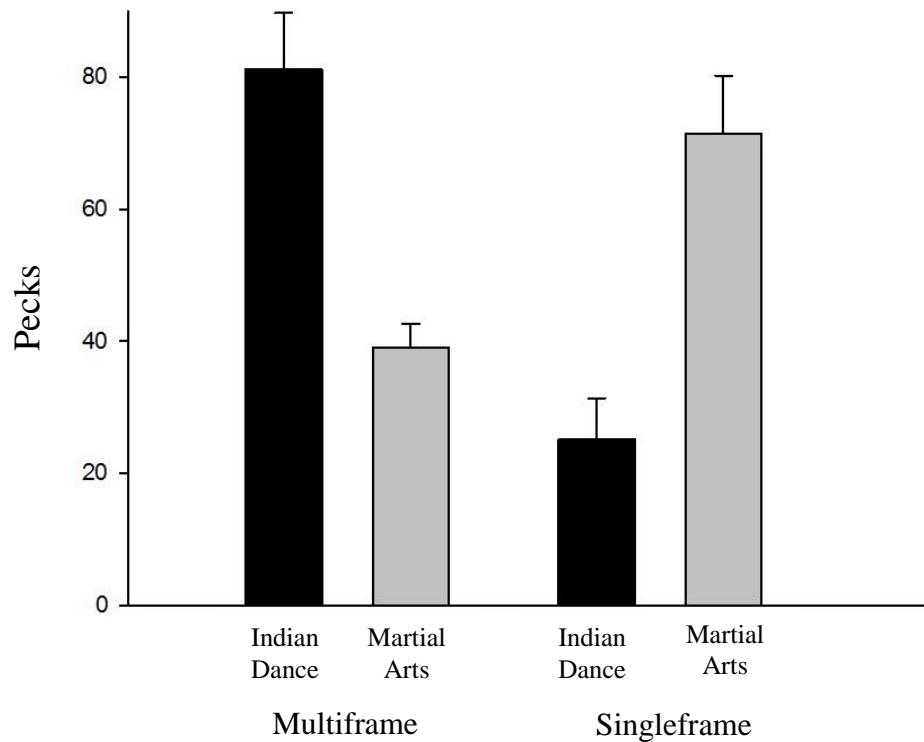

Figure 2. Initial discrimination across behavior and motion type. Error was calculated using standard error across bird. This data shows that birds could discriminate not only across behavior but across motion type as well.

Initial Transfer: In the first part of this experiment, the crucial feature extracted from the

data was the point at which the pigeons stopped responding to the pose duration videos in the same manner as "acting" videos. One way in which this can be analyzed is through multiple t tests to determine if the birds' responses to pose duration stimuli was significantly different between the behaviors. Results of those tests can be seen in appendix figure 2. These statistics show a wide range in which the birds do not respond significantly different to Indian dance and martial arts stimuli.

There is a visual method by which a more precise measurement of discrimination can be made however. The point at which the pigeons start to switch their responses for each behavior can serve as an indicator of how long they can integrate visual information. This response switch can be described by the physical point at which the data lines cross over one another in figure 3. This point demonstrates that at values below this, pigeons categorized the stimuli as acting and those above this point as stationary. By identifying this point at which responses begin to switch, an initial pose duration training value could also be chosen that would not prove too difficult for the pigeons to learn. The individual results for this first pose duration discrimination test can be found in appendix figure 1.
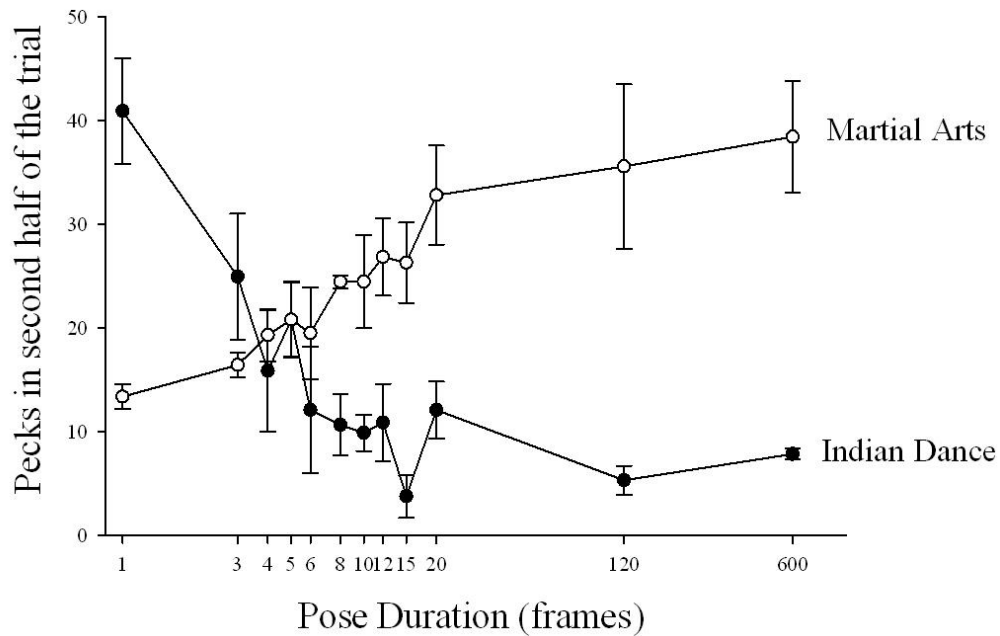
Figure 3. Initial discrimination of novel pose duration stimuli. This represents an average across the three birds tested. Individual results can be found in the appendix.

Extended Training: After the baseline crossover point was found, the pigeons began training where the original dynamic videos were replaced by pose duration videos. In the first phase, the baseline "acting" videos were switched from a pose duration of 1 frame to a pose duration of 5 frames. All three birds began training on a pose duration of 5 frames and subsequently showed a shift of their crossover point further to the right. This process of training (specific pose duration values) followed by transfer tests (with greater pose duration) was repeated until their discrimination no longer transferred to longer pose durations. The progression of the transfer tests can be seen for individual birds in figure 4. The three birds all successfully shifted to pose duration values between 75 and 100 frames, which is equivalent to approximately 2.5 seconds. Past these values, discrimination broke down for all three birds.
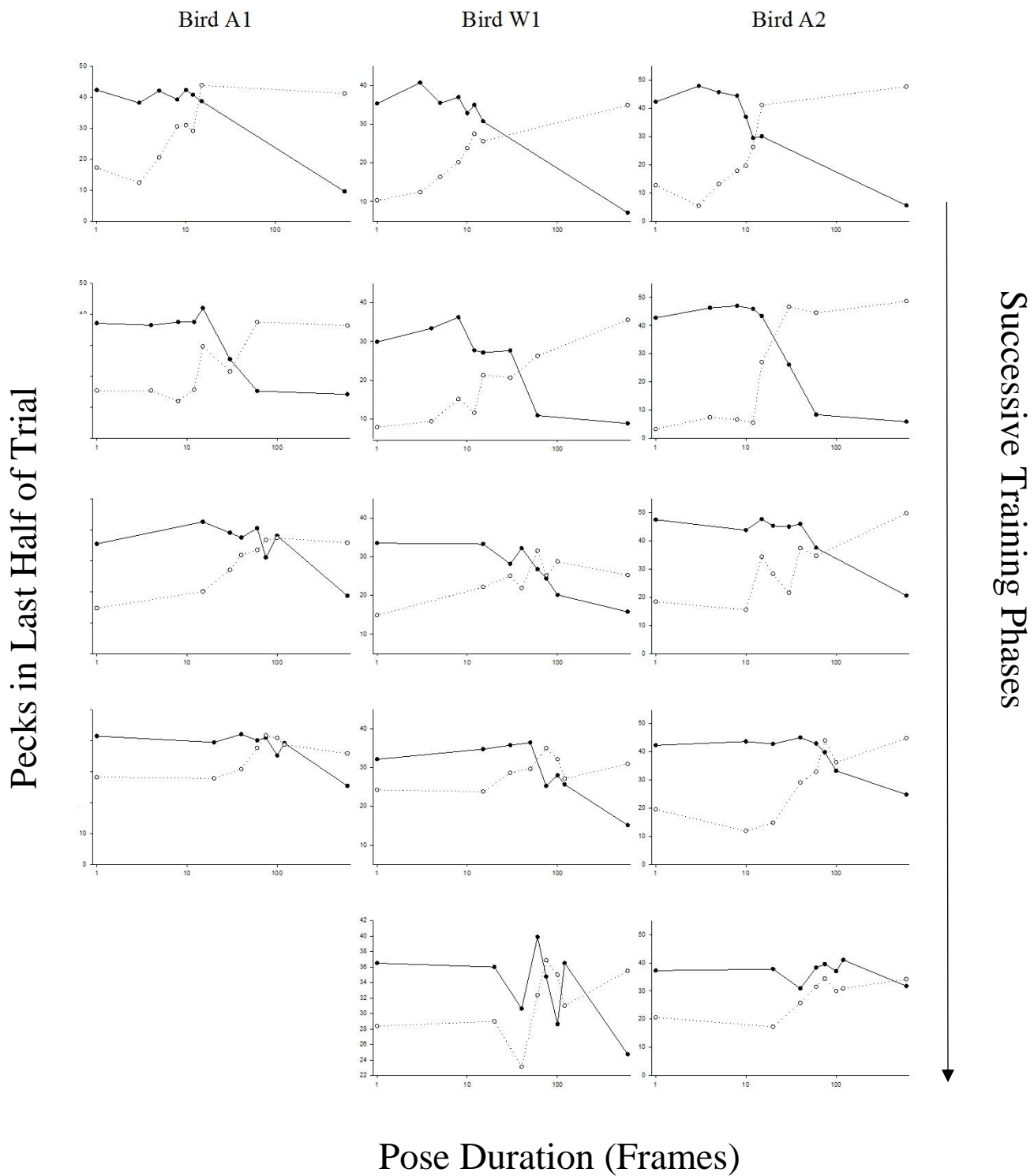
Figure 4. Transfer results for all three birds. Open circles represent Martial Arts behavior and closed circles represent Indian Dance behavior. Each column follows the successive transfer for an individual bird. For every bird the crossover point between the behaviors was successfully shifted farther to the right after each training session. Final transfer tests suggest the limit for over time comparisons of poses to be approximately 2.5 seconds.

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Discussion

The initial tests with the pigeons showed that without prior training, a high level of continuous motion was necessary for them to respond to the videos as acting. This is seen in their initial transfer where poses that were separated for longer than approximately 0.1 seconds were categorized as stationary stimuli. After training with these pose duration videos, the pigeons showed the ability to integrate poses that were separated for longer amounts of time. The birds showed consistent transfer to longer pose durations up until the pose duration value of 75 frames, which is equivalent to slightly more than 2 seconds for each pose. This supports the idea that with training, pigeons can integrate visual information over time such that more discontinuous videos can still be considered "acting".

This limit is still drastically shorter than what other studies have shown to be the length of time over which pigeons can integrate visual experiences. For example, in his change detection task, Wright et al. (2010) showed that pigeons could compare and recognize changes in stimuli that were separated by delays of up to 6,400 milliseconds, three times longer than what was seen in this experiment. A major difference to be noted between these studies is the complexity of the stimuli used. Wright et al.'s study used uniformly colored circles which are quite simple stimuli when compared to the computer generated 3-D human models used in this study. The human actors in this study hold a variety of unique poses in which their arms and legs are involved. In both Indian dance and martial arts, the poses vary widely in what they look like; for instance, limbs can be bent or straight, and feet and hands can even vary in position. Magnotti et al (2013) showed that as visual stimuli become more complex, the limit is short term memory decrease. Therefore, the complex nature of the stimuli used could account for the seemingly low limit of their visual short term memory.

It is important to note that as pose durations get larger, the difference between these videos and the stationary condition becomes smaller. As poses are held for longer amounts of times, they bear more resemblance to the stationary condition since the actor is stationary during these durations.

Given the complicated stimuli used in this experiment, it is possible that the birds were using some other cue rather than relying on mental representations stored in short term memory to make their decisions. As previously mentioned, perceptual cues have been shown across a variety of stimuli to contribute to discrimination (Qadri, Asen, & Cook, 2014; Troje & Aust, 2013). In such a temporally extended behavior sequence, there are multiple perceptual components that the pigeons could be attending to. One of these possibilities will be explored in Experiment 2.

Experiment 2

The goal of Experiment 2 was to determine if pigeons were bypassing memory mechanisms and instead were using other available features of the stimuli to make their discrimination. Two outstanding methods by which the pigeons could be making their discrimination are by using either long term memory or by using the remaining perceptual cues.

As the pose duration is extended, the total number of poses seen by the birds decrease. With fewer poses the relative significance of each unique pose increases. This implies that long term memory of specific poses could possibly be enough information for the pigeons to make their discrimination. It seems unlikely that this feature would contribute to discrimination given that in transfer sessions, the pigeons were exposed to new exemplars of each behavior and

continued to respond appropriately. As a precaution, videos with new poses were added into baseline for birds that passed the 60 frame pose duration training to discourage the use of specific pose information.

A perceptual cue that could have been serving as a cue for discrimination was also present in these stimuli. As the actor changes from one pose to another, a sudden, large scale shift is induced. This shift occurs at each pose change and involves the entire model shifting position and pose instantaneously. Although no motion is present between two sequential poses, this change will be referred to as a "jump" because it appears the actor is "jumping" from one pose to another pose. The relative significance of this jump as it applies to the pigeons' discrimination will be examined.

Methods

This feature test required that new sets of both static and various pose duration videos be made. In these videos, the idea was to replicate the instantaneous change resulting from pose changes known as the pose "jump". To do this, a camera "jump" was incorporated into all stimuli conditions. This camera jump forces additional motion on the human actor in the form of a large scale change by quickly shifting its spot in space, which results in the same type of instantaneous change produced by the pose jump.
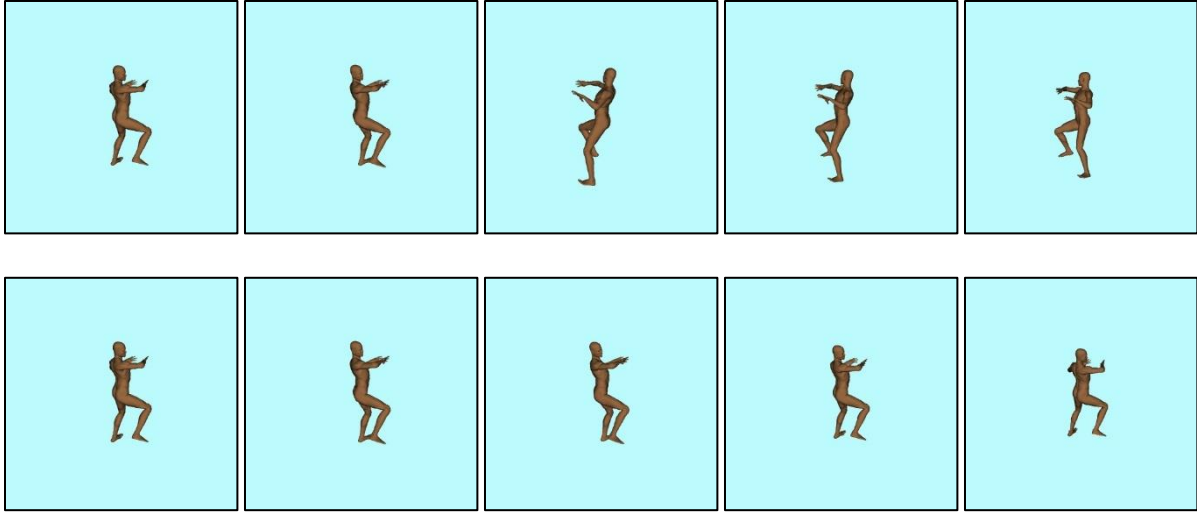
Figure 5. Sequence of stationary Indian dance video. The top strip shows the "jump" camera perspective, as evident by the view switch in the third frame. The bottom strip shows the normal, "smooth" camera path for the same stationary pose.

For videos of pose duration 30, the jump was integrated into the video at the same times as poses change. Stationary videos with camera jumps at the same corresponding pose change times were also created. By creating both dynamic and stationary videos with this camera jump, the pose jump could no longer serve as a discriminable cue. By masking this remaining cue, the pigeons would need to rely on comparisons of the stimuli over time using short term memory. Over four sessions, the pigeons completed 128 trials (64 S+, 64S-), where 16 trials were designated as probe trials.

Results

Results from this feature test show that the addition of a camera "jump" to simulate the pose "jump" disrupted pigeons' discrimination between positive and negative trials. This can be seen in the lack of separation in the jump conditions in Figure 6. For both behaviors, the birds failed to discriminate between pose duration videos and baseline videos (of pose duration 600)

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that both included a camera jump. Discrimination was significantly different for the original

smooth camera condition where $t(2)=24.714$, $p=.002$. For the camera "jump" condition, the birds

did not have significantly different responses on positive and negative trials as $t(2)= 0.978$,
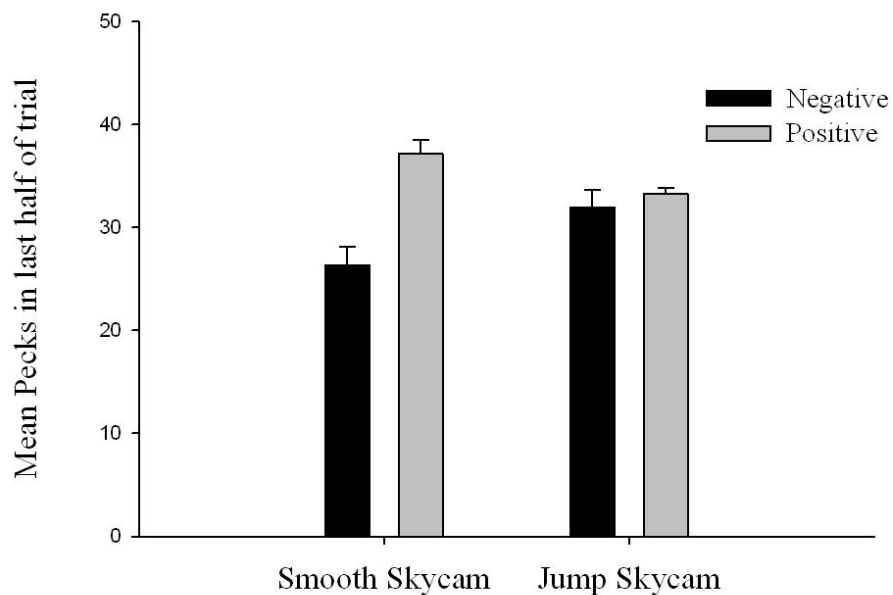
$p=.431$.

Figure 6. Peck rates in last half of trial for both "smooth" camera condition and "jump" camera condition. The separation in the "smooth" condition indicates significant discrimination, opposed to the lack of separation in responses to negative and positive trials for the "jump" camera condition.

Discussion

The results of this feature tests suggest that pigeons do not use the specific poses or pose

sequence but do rely on the jump cue inherent to these stimuli to make their discrimination. Once

this jump was added to all stimulus conditions, the birds' ability to discriminate between positive

and negative trials fell apart. This failure to continue discrimination indicates that the jump cue

was crucial to their original discrimination. The original purpose of Experiment 1 was to try and

force the birds to use short term memory to make their discrimination, but results from the jump

feature test show that the pigeons were instead relying on perceptual cues.

General Discussion

In these experiments, pigeons were tested with human models that acted in either an Indian Dance or Martial Arts behavior. Videos of models acting in these behaviors were developed such that the actor held his pose for certain number of frames before moving on to the next pose. This manipulation was introduced to study how long pigeons could integrate visual information over time. Since poses were held for a certain time before moving on, the idea was that to categorize these videos as "acting," the birds would have to retain some visual memory of what they had seen in previous frames so that they could compare what they were currently viewing. As the poses are held for longer durations, the ability to utilize short term memory to make the discriminations becomes more crucial since the actor is stationary for a longer period of time. The crucial information derived from this experiment was the limit at which the pigeons no longer categorized the pose duration videos as acting, suggesting that they were not recognizing that the poses were indeed changing. The limit occurred when poses were held for approximately 2.5 seconds, after which the pigeons could no longer integrate the disconnected poses to see the model as acting.

However, the videos possessed perceptual cues that could also allow for discrimination. A component that was hypothesized to contribute to discrimination was the "jump" that occurred when the actor changed poses. The second experiment tested the birds without this feature which did result in disrupted discrimination, indicating that the birds relied at least partially on this perceptual cue in order to make their discrimination.

The training on new pose durations that the pigeons received were initially implemented

to test the limits of short term visual memory. This design was meant to force the pigeons to utilize memory over the perceptual motion of the figure since longer pose duration values would surpass the capabilities of attentional capture. This would then require the birds to compare the present pose against past poses encoded in short term memory. However, given the results of the jump test, this training seemed to encourage the use of different perceptual components rather than the integration of pose information encoded in memory over time. Instead, it seems that the pigeons utilized a cue unique to these pose duration stimuli that was still accessible and arguably easier to attend to rather than maintaining memory of poses already seen. This cue also occurred at the same frequency as the pose changes which may be why we still see smooth curves in the birds' transfer data.

These results show similarities to studies done with these same human stimuli that investigated what components were necessary for discrimination between both behaviors and motion type. Qadri and Cook (2017) showed that both humans and pigeons used a combination of both form and motion cues to discriminate between the Indian dance and martial arts behaviors. The form cues are available based on the pose seen, whereas the motion cues are dependent on the flow of the actor's body, particularly the arms and legs. The results of Experiment 2 support the idea that the pigeons attend to change cues as the jump seemed to be a crucial cue for discrimination. One possible aspect of the jump cue that makes it such a crucial component for discrimination is that the entire figure undergoes the jump, making it a global cue. Studies have shown that although pigeons tend to utilize local cues over global ones to make discriminations, they still possess the ability to attend to global cues (Troje&Aust, 2013). The birds may still be attending, however, locally to certain areas of the figure, such as the limbs, and simply observing the effect of the jump in these areas of the stimuli. Further investigation is

needed to determine what aspects of this jump were crucial for the birds.

Throughout Experiment 1, the working threshold of the pigeons' short term memory was determined by what we referred to as 'the crossover point'. Although this provides a quick and simple way to see what their general discrimination is, it may not be as indicative of discrimination as desired. For the Indian dance behavior, pecks to acting stimuli are reinforced, whereas for the martial arts behavior, pecks to stationary stimuli are reinforced. In go/no-go tasks, it is commonly thought that since pigeons peck at most stimuli to begin with that the suppression of pecking on negative trials is a better indication of discrimination, as noted by Hagmann and Cook (2013). Therefore, the pigeons in this study would have to actively suppress pecking upon Indian Dance trials that were stationary and Martial Arts trials that were acting. This discrepancy alludes to the fact that the peck curves for each behavior are not necessarily reflecting the same discrimination. For the Indian Dance conditions, pigeons would have to suppress their pecking based on their ability to recognize stationary stimuli, but for Martial Arts condition, pigeons would suppress upon recognition of acting stimuli. This suggests that rather than rely on the crossover point between these two distinct discriminations, analyses of within behavior discrimination between acting and stationary might yield different and more accurate results.

Given the complicated nature of these acting stimuli, it is vital to determine the perceptual features that act as discriminatory cues so that they can be controlled for. If all perceptual features are accounted for, the pigeons are only left with using memory to make their decisions. If the birds were trained with such jump stimuli, they could learn to ignore and once again undergo a series of training and transfer tests to determine the capacity for their visual short term memory before the discrimination deteriorated. Preliminary evidence in this vein is

promising, suggesting that the pigeons can be trained to attend to use memory and ignore the momentary jump cue.

Exactly what features of these stimuli are encoded to make these comparisons over time is unknown. As previously mentioned, local and/or global features of the acting model could facilitate discrimination. Models of how biological motion is categorized suggest that there are multiple classes of neurons, including those that respond to local orientation. The form pathway put forth by Giese and Poggio (2003) shows how as the pathway progresses, the reference size detected by the neurons increases until it eventually encapsulates the entire figure. At this highest level where global cues are being recognized, individual 'snapshots' are smoothed into motion sequences. To make accurate comparisons of these acting models over time, this highest level of computation would certainly suffice, but the use of lower level neurons could also possibly prove sufficient for such action discriminations. As the pigeons rely on short term memory to conduct the discrimination, it will be important to identify which of these levels are represented in their short term memory.

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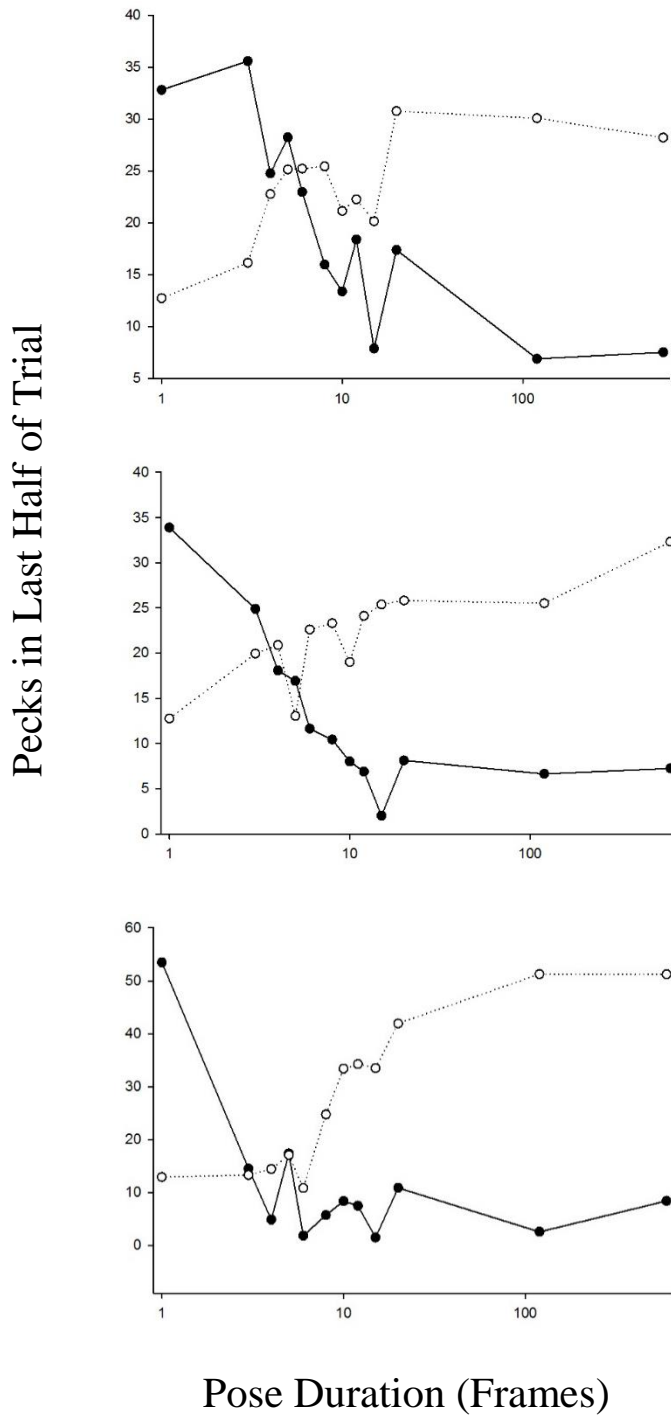
Appendix Figure 1

Initial pose duration transfer results for individual birds. Starting at the top are results for A1, W1, and A2, respectively.

Appendix Figure 2

Bird	Pose Duration (Frames)	t	df	p
A1	1	12.452	19	<.001
	3	3.935	7	.006
	4	.729	7	.490
	5	1.046	15	.312
	6	-.634	11	.539
	8	-2.107	11	.059
	10	-.972	3	.403
	12	-.873	3	.447
	15	-1.662	3	.195
	20	-2.614	7	.035
	120	-6.429	7	<.001
	600	-15.660	19	<.001
W1	1	17.936	19	<.001
	3	.912	7	.392
	4	-.862	7	.417
	5	.992	15	.337
	6	-5.231	11	<.001
	8	-2.382	11	.036
	10	-3.086	3	.054
	12	-3.015	3	.057
	15	-4.917	3	.016
	20	-4.106	7	.005
	120	-3.808	7	.007
	600	-25.336	19	<.001
A2	1	26.54	19	<.001
	3	.242	7	.815
	4	-1.807	7	.114
	5	.075	15	.941
	6	-2.806	11	.017
	8	-3.279	11	.007
	10	-4.454	3	.021
	12	-4.396	3	.022
	15	-5.246	3	.013
	20	-3.849	7	.006
	120	-12.410	7	<.001
	600	-25.662	19	<.001

Table 1. Paired t-test results for individual birds on their initial pose duration discrimination.