

# Differential Effects of Visual Context on Pattern Discrimination by Pigeons (*Columba livia*) and Humans (*Homo sapiens*)

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Three experiments examined the role of contextual information during line orientation and line position discriminations by pigeons (*Columba livia*) and humans (*Homo sapiens*). Experiment 1 tested pigeons' performance with these stimuli in a target localization task using texture displays. Experiments 2 and 3 tested pigeons and humans, respectively, with small and large variations of these stimuli in a same-different task. Humans showed a configural superiority effect when tested with displays constructed from large elements but not when tested with the smaller, more densely packed texture displays. The pigeons, in contrast, exhibited a configural inferiority effect when required to discriminate line orientation, regardless of stimulus size. These contrasting results suggest a species difference in the perception and use of features and contextual information in the discrimination of line information.

Humans typically show facilitation in the discrimination of line stimuli with the addition of redundant, seemingly uninformative, contextual information. This improvement in discriminating or grouping stimuli in the presence of redundant contextual information has been shown in a number of experiments (Enns & Prinzmetal, 1984; Pomerantz, 1981; Pomerantz & Pristach, 1989; Pomerantz, Sager, & Stoeber, 1977; Weisstein & Harris, 1974). In the *configural superiority effect*, for instance, humans discriminate oblique lines faster or more accurately when these lines are presented in a context of horizontal and vertical lines (the configural condition) than when they are presented alone (the element condition—see examples in Figure 1; see also Enns & Prinzmetal, 1984; Pomerantz, 1981; Pomerantz & Pristach, 1989; Pomerantz et al., 1977). This improvement in discrimination performance has been attributed to the introduction of emergent features, such as closure, connectedness, intersections, and symmetry, by the additional line segments (Julesz, 1975, 1981).

Comparative experiments with pigeons have not been able to establish a similar beneficial effect. Donis and Heinemann (1993) found that pigeons discriminating line stimuli presented in similar configural contexts showed an interference effect or a *configural inferiority effect*. This contradictory influence of contextual information on discrimination may be an important marker for how line information is processed or subsequently grouped to form objects

by each of these species. In this vein, Cavoto and Cook (2001) recently found that pigeons show a local advantage in the discrimination of hierarchically arranged information, whereas humans typically show a global advantage (but see Fremouw, Herbranson, & Shimp, 1998). Such a potential species difference becomes even more interesting in the context of the growing number of other recent studies reporting similarities in the pattern recognition, object perception, and categorization abilities of pigeons and humans (e.g., Blough, 1984, 1985; Cook, 1992a, 1992b, 2001b; Cook, Cavoto, & Cavoto, 1996a, 1996b; Cook, Cavoto, Katz, & Cavoto, 1997; Cook, Katz, & Kelly, 1999; Kirkpatrick-Steger, Wasserman, & Biederman, 1996). Exploring how and at what level the perceptual processes of pigeons and people are similar or different is a key psychological issue because these two species each represent one of the two major classes of visually dominant vertebrates to have evolved on this planet (Cook, 2001b; see also Cook, 2001a, for chapters examining this fundamental issue at a number of different levels).

Two main explanations have been offered to account for the differential use of context information by these two species. One explanation, suggested by Donis and Heinemann (1993), is that humans are able to combine visual encoding and nonvisual encoding processes, such as verbal labeling, to perform the discrimination tasks. For example, humans might attach verbal labels such as *arrow* and *triangle* to the configural stimuli. This dual encoding facilitates the retrieval of the relevant information needed for the discrimination by humans. Because such verbal coding is not available to pigeons, they are distracted by the addition of the contextual information (see also Chase & Heinemann, 2001; Heinemann & Chase, 1990).

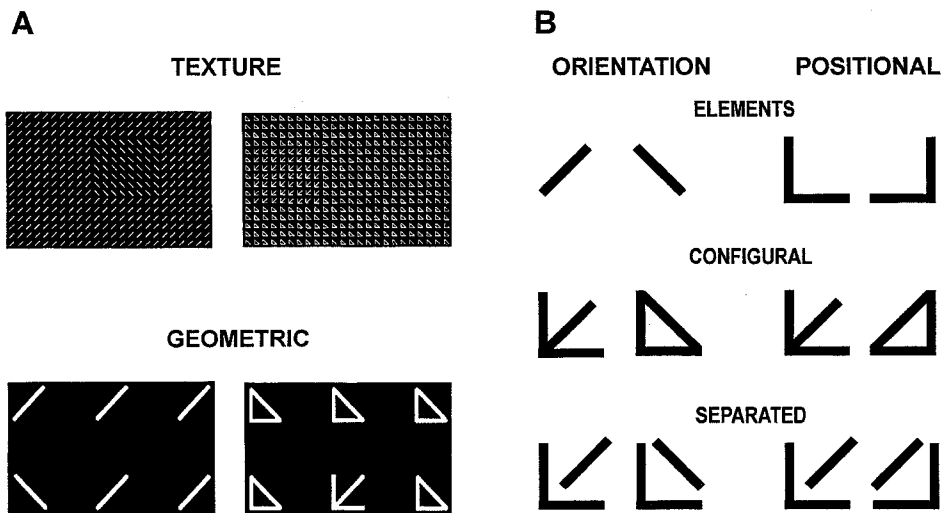
A second explanation is based on possible differences in perceptual coding processes. For instance, many investigations of pigeons' pattern and object perception have reported that pigeons show a strong tendency or bias to encode local features even in the presence of informative global or spatial cues (e.g., Aust & Huber, 2001; Cavoto & Cook, 2001; Cerella, 1977, 1980; Delius & Hollard, 1995; Towe, 1954). Cerella's (1980) report is perhaps the classic example of local encoding by pigeons. He showed that

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**Figure 1.** A: Examples of the display types (texture and geometric) used in the experiments. The top two illustrations show orientation displays of the element condition (left) and the configural condition (right) in Experiment 1. The bottom two illustrations show orientation displays of the element condition (left) and the configural condition (right) in Experiments 2 and 3. B: Examples of the orientation and positional stimulus sets.

pigeons could discriminate line drawings of the cartoon character Charlie Brown from other characters in the comic series. However, when the individual images of the characters were scrambled such that large body divisions were no longer in biologically correct positions, the pigeons could still discriminate Charlie Brown from the other characters. This accurate performance in the scrambled condition supported the idea that pigeons were encoding the stimuli at a more local or featural level. If pigeons have a bias to encode images or patterns at a more local or elemental level in some settings (Cavoto & Cook, 2001) or perhaps to use different fundamental features to encode line stimuli (e.g., Allan & Blough, 1989; Blough & Blough, 1990), then one might anticipate that in line orientation discrimination experiments, such as Donis and Heinemann's (1993), additional contextual information might hinder discrimination performance by hiding or altering the critical local features used by the pigeons to perform the orientation discrimination.

In the current study, we further examined the effects of added context on line orientation discriminations by pigeons. Using several different procedures and stimulus sets, we attempted to better establish whether there is a true comparative difference between humans and pigeons in this particular regard. Specifically, we tested whether the addition of identical line contexts to an oblique line discrimination would facilitate or interfere with the discrimination by pigeons and humans. One type of stimulus configuration was similar to that tested by Donis and Heinemann (1993). This task required pigeons and humans to discriminate between obliquely oriented lines presented alone (element condition) or to make the same discrimination within an identical context composed of horizontal and vertical lines (configural condition). Examples of these two conditions can be seen in Figure 1B in the orientation stimulus set. In addition, we also examined a second type of configuration effect that had not been tested with pigeons before based on the relative position of the line elements. This required discrimination between an L and a mirror-reversed L

(element condition) or the same discrimination within the context of an additional single oblique line (configural condition). Examples of these two conditions can be seen in Figure 1B in the positional stimulus set.

In Experiment 1, we retroactively examined the performance of pigeons with these stimuli in a target localization task involving densely packed texture stimuli composed of many small elements. In Experiment 2, we examined the performance of pigeons with these stimuli in a same-different task using both small and large size variations of each set. In Experiment 3, we examined the performance of humans with these same stimuli in a same-different task. In each case, we were interested in whether the contextual lines would produce a configural superiority or inferiority effect for each stimulus set.

### Experiment 1

This first study involved mining data from a prior project examining texture perception in pigeons (Cook, 1992a, 1992b; Cook et al., 1996a, 1997). The 5 pigeons in Experiment 1 had received, as a routine part of their daily training sessions during that time, texture displays composed of the stimulus sets similar to those in Figure 1A. For this experiment, we analyzed a large corpus of training data that had been collected over the years (and during other experiments) to examine if the pigeons showed any form of configural effect with these texture displays. For this purpose, we specifically extracted only those trials that had used a combination of orientation and positional elements or configural stimuli.

### Method

#### Animals

Five highly experienced male White Carneaux pigeons (*Columba livia*; Palmetto Pigeon Plant, Sumter, SC) were tested. These pigeons had pre-

viously participated in numerous experiments (Cook, 1992a, 1992b, 1993; Cook et al. 1996a, 1997). They were maintained between 80% and 85% of their free-feeding weights. The pigeons were individually housed in large cages with free access to water and grit. The colony was on a 12-hr light-dark cycle.

### Apparatus

Training and testing were conducted in a flat-black Plexiglas chamber (38 cm wide  $\times$  36 cm deep  $\times$  38 cm high). All stimuli were presented on a color computer monitor (NEC MultiSync 2A, Wooddale, IL) and viewed through a 26  $\times$  18 cm window in the middle of the front panel of the chamber. A thin piece of glass was mounted in the viewing window to protect the surface of the monitor. Pecks directed to the monitor screen were detected by an infrared touch screen (resolution of 80  $\times$  48 pixels; EMS Systems, Champaign, IL) mounted behind a 40 mm wide Plexiglas ledge surrounding the inside edge of the viewing window. A 28-V house light located in the ceiling was illuminated at all times, except when an incorrect choice was made. A food hopper was located in the middle of the front panel, with its access hole flush to the floor. Infrared beams located in the food hopper measured head entries. All experimental events were controlled and recorded by computer.

### Stimuli

All stimuli were presented as texture displays (e.g., see top row of Figure 1A). Over the time period that these data were collected, the size and shape of the texture displays were varied slightly as new procedures and technology became available for this type of testing. In general, the size of each texture display was 20  $\times$  13 cm. The elements making these displays were a variety of different colored shapes against a uniform black background, consisting of 468 individual elements (each approximately 7  $\times$  7 mm; length  $\times$  width) evenly spaced across 26 columns and 18 rows, although some of the earlier data were collected using 24-column, 16-row displays. The pigeon's task was to locate the odd or different target area (7  $\times$  7 mm elements, although 8  $\times$  7 mm and 7  $\times$  6 mm sizes were tested during some of the earlier stages) that was randomly located in each display. During the analyzed sessions, color and shape trials were constructed using randomized combinations of more than 40 shapes and more than 20 different colors (examples can be found at [www.pigeon.psy.tufts.edu/jep/blick/blick\\_elements.htm](http://www.pigeon.psy.tufts.edu/jep/blick/blick_elements.htm)). For the purposes of analysis, only trials consisting of the following stimulus pairs were included in the analysis:

1. The orientation stimulus set consisted of either oblique lines (element condition) or oblique lines in context (configural condition). The stimuli of the element condition were positively and negatively sloped diagonal lines. The stimuli of the configural condition were positively and negatively sloped lines embedded within a redundant L-shaped context.

2. The positional stimulus set consisted of either L-shaped elements (element condition) or L-shaped elements in context (configural condition). The stimuli of the element condition were a capital L and a mirror-image L. The stimuli of the configural condition were the capital L and the mirror-image L embedded on a positively sloped line. All of these elements had an equal chance of appearing in either the target region or the distractor region of a display and an equal chance of being tested in each daily session. All had been part of the pigeons' training set for at least 1 year prior to the results reported below.

### Discrimination Testing

Each trial began with an orienting stimulus, consisting of a white circle on a black background. A single peck terminated the orienting stimulus, and a texture display was randomly presented. If the pigeon responded correctly (i.e., five pecks accumulated to the target region before five pecks accumulated to the distractor region), the display was turned off and the

pigeon was permitted 2 s access to the food hopper. If the pigeon responded incorrectly (i.e., five pecks accumulated to the distractor region), the display was terminated and the overhead house light was turned off for a brief period of time (depending on the stage of testing, timeouts varied from between 5 and 15 s). Trials were separated by a 5-s intertrial interval (ITI) during which the house light was illuminated. The chance level of performance in this target localization test is approximately 30% as determined by behavioral tests with uniform displays (Cook et al., 1996a).

Daily sessions for the time period analyzed consisted of between 140 and 200 trials, depending on the structure of any ongoing experiments focused on testing other aspects of texture perception. Because of this and the randomized nature of element selection, the trials of interest for the current study were typically only a minuscule portion of any daily session. To guarantee a sufficient sample size, we selected 425 sessions for each bird from slightly over 2 years of testing for the purpose of further analyses. These sessions were organized into five blocks of 85 sessions. The number of trials for each condition ranged from 507 (positional set, element condition) to 809 (orientation set, configural condition). The number of trials for each pigeon ranged from 518 (Birds 7 and 5) to 589 (Bird 2).

### Results

The results of this analysis are shown in Figure 2. For the orientation stimulus set, a configural inferiority effect was found. Overall, the pigeons showed significantly higher accuracy at locating the target in the element condition (55.7%) than in the configural condition (40.5%; see Figure 2A),  $F(1, 4) = 12.7$ ,  $p < .05$ . In contrast, a configural superiority effect was found for the

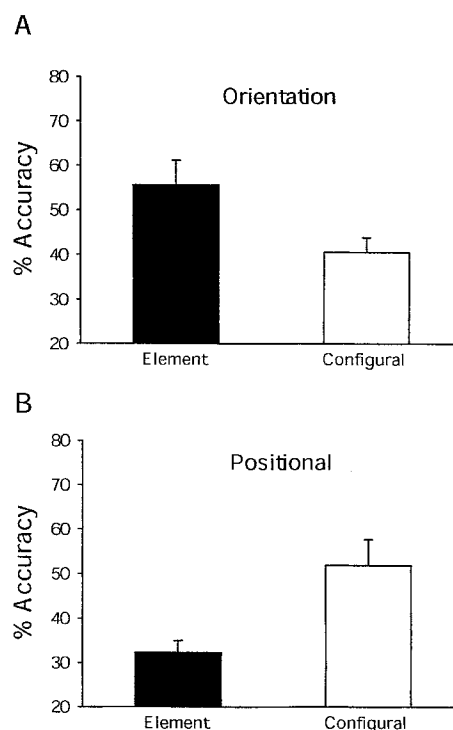


Figure 2. Pigeons' average percentage accuracy to the texture displays presented in Experiment 1. A: Percentage accuracy for the orientation set in the element and configural conditions. B: Percentage accuracy for the positional set in the element and configural conditions. Error bars represent standard errors of the sample means.

positional set. The pigeons showed a significantly lower accuracy locating the target in the element condition (32.3%) than in the configural condition (51.9%; see Figure 2B),  $F(1, 4) = 8.0, p < .05$ . Performance in the latter configural condition was found to be significantly above chance,  $t(4) = 3.8, p < .05$ , whereas performance in element condition was not,  $t(4) = 0.9, p < .10$ .

### Discussion

The results of this experiment suggest that contextual information serves to both degrade and enhance pigeon target localization with textured stimuli. The birds consistently showed better accuracy at discriminating the elements of the orientation set when it was presented alone than when it was embedded in the configural context. Thus, the added contextual information degraded the pigeons' ability to discriminate between the oblique lines. In contrast, the pigeons consistently showed better accuracy at discriminating the configural condition of the positional set in comparison with the element condition of the positional set. Thus, the contextual information in the positional set enhanced the pigeons' ability to discriminate the component elements of the positional set.

Overall, these results suggest that the configural inferiority effect, at least as tested with an oblique line discrimination, is a robust phenomenon in pigeons. This experiment builds on Donis and Heinemann's (1993) findings involving successive single stimulus presentations in a choice discrimination by showing that the same effect can be found with simultaneously presented, small, multielement displays in which the pigeons had to search out and localize an odd target. Further, this configural inferiority effect was present in the birds' data for at least 2 years and long after the pigeons were overly familiar with the stimuli. This longevity indicates that the origins of this effect are likely perceptual in nature and are not greatly affected by experience, suggesting a minimal contribution from learning and memory.

In contrast to the orientation results, the positional stimulus set showed a configural superiority effect. One key to understanding this result involves the discrimination required with the basic element stimuli. It requires the pigeons to make a subtle discrimination on the basis of the position of the vertical line along the horizontal line and to do the same between mirror-reversed stimuli. Research has shown that pigeons, similar to humans, may have difficulty discriminating between mirror-image stimuli (Todrin & Blough, 1983; however, see Delius & Hollard, 1995). Our results may support this notion. The pigeons' performance with the elements was very poor and not significantly better than chance, indicating that this was a hard discrimination for the pigeons. Given this difficulty, the addition of the context can only help, most likely by adding features not present in the elements or by breaking up the symmetry. Although the orientation stimuli also require a mirror-image discrimination, in the positional stimuli, the lines are oblique and do not align with the main axis of orientation, which may make this type of discrimination easier (Donis, 1999).

### Experiment 2

Experiment 2 examined orientation and positional stimulus sets for configural effects by testing new birds in a same-different task. Along with tests involving the multielement texture displays used

in Experiment 1, visual search displays, using more sparse displays and larger elements, were introduced and tested. Examples of these new geometric displays can be seen in Figure 1A. By manipulating the size and number of items in the display, we wanted to further test the generality and robustness of the effects detected in Experiment 1. As suggested by previous research, search difficulty may be affected by increasing the number or oddity of items displayed (e.g., Young, Wasserman, & Garner, 1997; Zentall, Edwards, Hearst, & Hogan, 1980; Zentall, Edwards, & Hogan, 1980).

This second experiment also included two additional stimulus manipulations designed to further investigate the perceptual origins of any configural effects. These involved changes in element size and feature separation. Three different stimulus sizes were tested with the geometric displays to examine the potential role of stimulus size. Smaller stimulus elements may encourage the pigeons to process the entire stimulus display on a more global or configural level (Cook, 2001b). If so, then one might see more effects of the added context in the small element conditions. To better understand the effects of the added context, we also manipulated the spatial contiguity of the configural features. In these *separated* conditions, the target features and context were separated in space on the display (see bottom illustrations in Figure 1B). Thus, these separated conditions provided the same visual information as the configural stimuli but eliminated any emergent features (e.g., closure or connectedness) directly created by the spatial proximity or grouping of the context and the critical discriminative features. Thus, the comparison of performance in the separated conditions and standard context conditions permits a better isolation of which stimulus features are critical to producing configural effects.

### Method

#### Animals

Four highly experienced male White Carneaux pigeons were tested. No preliminary training was needed, as each pigeon had several years experience with the same-different task (Cook et al., 1997; Cook, Katz, & Kelly, 1999). They were maintained between 80% and 85% of their free-feeding weights. The pigeons were individually housed in large cages with free access to water and grit. The colony was on a 12-hr light-dark cycle.

#### Apparatus

Training and testing were conducted in a flat-black Plexiglas chamber (38 cm wide  $\times$  36 cm deep  $\times$  39 cm high). Stimuli were presented on a color computer monitor (COMPAQ 151FS, Houston, TX) and were visible through a 27.5  $\times$  21.0 cm viewing window centered in the front panel. The viewing window's bottom edge was 18 cm from the chamber floor. Mounted 2 cm from the monitor was a touch screen (Elographics Accu-Touch Model E274-SFC, Oak Ridge, TN), which was used to detect pecks directed at the screen. A thin clear sheet of acetate was placed in front of the touch screen to protect it from direct contact. A 28-V house light was located in the ceiling of the chamber and was illuminated at all times, except when an incorrect choice was made. Three identical food hoppers (Coulbourn #E14-10, Allentown, PA) were located as follows: one in the center of the front panel, one on the left wall, and one on the right wall. Only the two side hoppers were used during this experiment; the center food hopper was inactive. Infrared LEDs mounted 1.5 cm within each hopper were used to detect head entries. All experimental events were controlled and recorded with a 486-class computer. A video card (VGA

Wonder; ATI Technologies, Scarborough, Ontario, Canada) controlled the monitor in the super video graphics array (SVGA) mode (800 × 600 pixels).

## Display Organization

The construction and organization of texture and geometric displays used in this study were essentially the same as described in detail in Cook et al. (1997). As such, only brief descriptions of the stimuli and any procedural differences are noted below. The overall display size was 18 × 12 cm and arranged as either a texture or visual search display. Texture displays consisted of 384 elements (3 to 7 mm in size) arranged in a 24 × 16 matrix at 0.75-cm intervals. The different displays contained a randomly located 8 × 7 mm target region with a surrounding region of distractor elements. The same displays were constructed by repeating the same element at each location. In the visual search displays, elements were organized in a 3 × 2 matrix. In different displays, 1 element differed from the surrounding 5 distractors along either the dimension of color or shape. The same displays were made by repeating the same element at each of the six locations. In total, the pigeons experienced five different classes of intermixed same-different displays (texture, geometric, feature, object, and photographic) during their daily testing. For the purposes of this investigation, only the texture and geometric displays were used in presenting the critical test stimuli as described in the next section. Details about the other displays are available in Cook et al. (1997, 1999). In brief, feature displays differed from texture displays in having local irrelevant variation across the display in either the color or shape value of the component elements. Object and photographic differed from geometric displays by using either digitized depictions of natural objects or colored photographs, respectively, as their component elements.

## Test Stimuli

One element size of test stimuli (approximately 5 to 7 mm) was tested with the texture displays. Three different element sizes were tested with the geometric displays and were labeled *small* (approximately 7 × 7 mm), *medium* (approximately 13 × 13 mm), and *large* (approximately 20 × 20 mm). Any particular display tested only one size.

The orientation stimulus set consisted of oblique lines (element condition), oblique lines in a spatially contiguous context (configural condition), or oblique lines in a spatially displaced context (separated condition). The stimuli of the element condition were again positively and negatively sloped diagonal lines. The stimuli of the configural condition were positively and negatively sloped lines embedded within a redundant L-shaped context. The stimuli of the separated condition were positively and negatively sloped lines embedded within a redundant L-shaped context, with the latter context displaced a short distance away (see Figure 1B).

The positional stimulus set consisted of L-shaped elements (element condition), L-shaped elements in spatially contiguous context (configural condition), or L-shaped elements in spatially displaced context (separated condition). The stimuli of the element condition were a capital L and a mirror-image L. The stimuli of the configural condition were the capital L and the mirror-image L with a positively sloped line added to its interior. The stimuli of the separated condition were the capital L and the mirror-image L with the positively sloped line displaced a short distance away.

## Discrimination Testing

Each trial began with a peck to the ready signal, followed by the presentation of a randomly generated same or different display. On completion of a peck requirement to the display, the left and right "choice" hoppers were illuminated, allowing a choice to be made by the pigeon. If the correct hopper was chosen, it was raised for 2 s. If the incorrect hopper was chosen, the hopper lights were turned off and the overhead house light

extinguished for 15 s. The stimulus display remained visible until the pigeon made a choice. For 2 of the pigeons, the left hopper was correct following same displays, and the right hopper was correct following different displays. This was reversed for the other 2 pigeons. An 8-s ITI separated each trial.

A target-directed/fixed-ratio (TD-FR) procedure was used for stimulus presentation. In this procedure, the pigeons were required to peck five times at the target of the different displays to enter a trial's choice phase. Pecks to the distractor area of the different displays were recorded but not counted toward completion of the TD-FR requirement. Because same displays have no target area to peck, the number of pecks required to enter the choice phase of these trials were individually yoked to prior different trials of that specific display type, so as to ensure that an equivalent number of pecks were made to each trial type.

In total, the experiment consisted of four successive test phases. Each involved slightly different combinations of trials testing the orientation and positional test stimuli. For the purposes of the analyses provided below, we have combined the four phases and treated them as one larger experiment. This was done because our preliminary analyses revealed no substantive differences between the different test phases.

*Phase 1.* This phase lasted 22 sessions. Each session consisted of 160 trials. Twenty-four of these were test trials consisting of 12 texture displays (6 same and 6 different displays) and 12 large geometric displays (6 same and 6 different displays). Each of these two display types tested stimuli from only the orientation stimulus set. Four element, four configural, and four separated displays were tested with each stimulus type. The remaining 136 trials of each session consisted of a randomized mixture of randomly constructed texture, feature, geometric, object, and photographic same and different displays.

*Phase 2.* This phase lasted 14 sessions. Each session consisted of 160 trials. Twenty-four of these were test trials consisting of geometric displays testing the small (6 same and 6 different displays) and medium stimulus sizes (6 same and 6 different displays). Once again, only the orientation stimulus set was tested. Four element, four configural, and four separated displays were tested with each stimulus size. Each of these displays was counterbalanced so that each stimulus element appeared equally often as target and distractor. The remaining 136 trials of each session consisted of testing a randomized mixture of texture, feature, geometric, object, and photographic displays.

*Phase 3.* This phase lasted 14 sessions. Each session consisted of 160 trials. Forty-eight of these were test trials consisting of 12 texture displays and 12 small, 12 medium, and 12 large geometric displays. This time each of the display types tested stimuli from only the positional stimulus set. Four element, four configural, and four separated displays were tested with each stimulus type and size. Each of these displays was counterbalanced such that each stimulus element appeared equally often as a target item and as a distractor item. The remaining 112 trials of each session consisted of testing a randomized mixture of texture, feature, geometric, object, and photographic displays.

*Phase 4.* This phase lasted 12 sessions. Each session consisted of 192 trials. Ninety-six of these were test trials consisting of 24 texture displays and 24 small, 24 medium, and 24 large geometric displays. Half of each stimulus type and size tested the orientation stimulus set, and the other half tested the positional stimulus set. Each of these sets tested four element, four configural, and four separated displays. Each of the displays was counterbalanced so that each stimulus element appeared equally often as a target item and as a distractor item. The remaining 96 trials of each session consisted of testing a randomized mixture of texture, feature, geometric, object, and photographic displays.

## Results

Although line discriminations can be difficult for pigeons, accuracy with the texture and geometric display types was moderate.

and stable throughout testing for 3 of the 4 pigeons (Bird 1A = 66.9%, Bird 2B = 66.1%, and Bird 3R = 72.2%). The 4th bird (Bird 4J = 54.8%) performed at chance levels with the test stimuli, and its data were excluded from all further analyses. Overall, mean accuracy for the 3 pigeons was 71.9% for the orientation stimuli (texture = 75.2% and geometric = 68.5%) and 67.8% for the position stimuli (texture = 71.0% and geometric = 64.5%).

For the texture displays, a configural inferiority effect was again found for the orientation stimuli,  $F(2, 4) = 9.2, p < .05$ . A Duncan's test showed a significant difference between the element condition (80.2%) and the configural condition (74.8%), the element condition and the separated condition (70.5%), and the configural condition and separated condition in the orientation stimulus set ( $ps < .01$ ; see Figure 3A). No significant differences were found with the conditions in the positional stimulus set for the texture display presentations,  $F(2, 4) = 0.3, p > .05$  (see Figure 3A).

With the geometric displays, a configural inferiority effect was again found for the orientation stimuli. A repeated measures analysis of variance (Condition  $\times$  Stimulus Size) revealed no significant main effect or interaction with stimulus size, but a significant main effect of condition was found,  $F(2, 4) = 16.2, p < .05$ . Further comparisons confirmed that significantly higher choice accuracy was obtained with the element condition (72.2%) than with either the configural condition (66.5%; see Figure 3B),  $t(2) = 5.7, p < .05$ , or the separated condition (67.0%),  $t(2) = 5.6, p < .05$ . No significant difference was found between the latter two conditions. For the positional stimulus set, there were no

significant differences found among any of the conditions or as a function of stimulus size.

### Discussion

The pigeons in Experiment 2 showed a configural inferiority effect for orientation stimuli in both texture and geometric displays. The results for the texture displays replicate those found in Experiment 1 and extend them to a choice task involving the discrimination of same and different displays. The results for the geometric displays further extend these findings by showing a configural inferiority effect in displays that were more sparsely constructed, made with many fewer elements, and made with several different sizes of elements. We found no effect of the latter size manipulation with displays, suggesting that, at least over the range tested here, this had no influence on the discrimination of these displays.

No configuration effect of any type was found for the positional stimuli. There were trends in both displays suggesting the same type of configural superiority effect as detected in Experiment 1, but none of these reached statistical significance. The positional stimuli were again much harder for the pigeons to discriminate overall, resulting in more variability in their scores. This difficulty most likely stems from the positional and mirror-reversed nature of these stimuli. Although a final judgment needs to be reserved pending more data, the results of Experiment 1 and the trends in Experiment 2 do suggest that for some discriminations pigeons may benefit from the addition of context-based configural features.

In combination, the results of Experiment 1 and 2 demonstrate the existence of an orientation-based configural inferiority effect across two different display organizations (texture and geometric), four different stimulus sizes, two different types of discrimination tasks (target localization and same-different task), and two sets of pigeons. From this, it seems safe to conclude that this configural inferiority effect is a robust phenomenon in pigeons. Thus, stimuli that normally facilitate the human discrimination of line orientation instead consistently degrade the pigeons' discrimination of the same information. This suggests that the pigeons are not perceptually processing the emergent features of the configural stimuli in the same way as humans.

### Experiment 3

Before concluding that there is a species difference in the processing of such contextual information, however, we had to determine that the above results are not tied to the specific stimuli or tasks used to test the pigeons. Experiment 3 examined this possibility by testing human participants with the same stimuli and task as used in Experiment 2.

### Method

#### Participants

Ten volunteer human (*Homo sapiens*) participants served in this study. All had normal or corrected vision. Participants recruited for the experiment were told they would be performing a simple visual discrimination task on a computer.

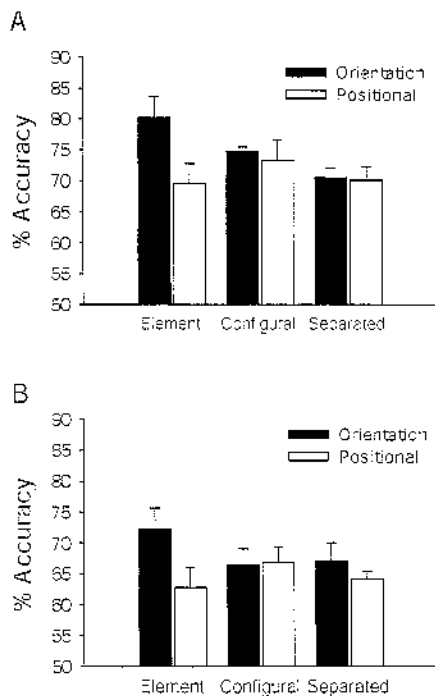


Figure 3. Pigeons' average percentage accuracy for the texture (A) and geometric (B) displays used in Experiment 2. Error bars represent standard errors of the sample means.

### Apparatus and Procedure

All stimuli were presented on a color computer monitor. Participants were seated approximately 50 cm from the monitor with the keyboard within easy reach. All experimental events were controlled and recorded with a 486-class computer. The keyboard was used to record the participant's responses. A video card (VGA Wonder; ATI Technologies, Scarborough, Ontario, Canada) controlled the monitor in the SVGA mode (800 × 600 pixels).

On arrival, each participant was asked to sit in front of the computer monitor. The participant was given the following instructions. He or she would be performing a visual discrimination task. The task required that the participant determine if the stimuli presented on the computer monitor were all the same or if some of the stimuli were different from the others. Participants were instructed to press the *F* key if all the stimuli on a display were the same and to press the *J* key if one or more were different (reversed for half the participants). Participants were also informed that if they were incorrect they would be presented with a blue screen for a short time. They were instructed to respond as quickly and accurately as possible. The participants were then given 10 warm-up trials to learn the procedure using randomly selected examples of generic texture, geometric, object, and photographic displays as experienced by the pigeons during their daily testing in Experiment 2.

### Discrimination Testing

The stimuli and organization of the next 96 trials were identical to those used in Phase 4 of Experiment 2 with the pigeons. Each trial began with an orienting stimulus presented for 0.75 s. Following the orienting stimulus, the participants were presented with either the same or different displays, and their responses were collected. If a participant's keyboard response was correct, the stimulus display was turned off and the 5-s ITI began. If the participant's keyboard response was incorrect, a blue screen appeared for 2 s, followed by the ITI. Each participant received one session of 106 trials, which was composed of the 10 warm-up trials followed by 96 randomly ordered test trials.

### Results

Human participants showed all of the standard effects previously reported, with the geometric displays supporting a configural superiority effect (Enns & Prinzmetal, 1984; Pomerantz, 1981; Pomerantz & Pristach, 1989; Pomerantz, Sager, & Stoeber, 1977; Weisstein & Harris, 1974) and the texture displays not supporting such an effect (Julesz, 1975, 1981; Pomerantz, 1981; Pomerantz & Pristach, 1989). In the following analyses, only correct responses were analyzed, and the few trials with errors (< 1%) were discarded.

For the geometric displays, the orientation stimulus set showed a configural superiority effect (see Figure 4B). Search reaction times for configural stimuli (862 ms) were significantly faster than for element stimuli (1,070 ms) on different display trials,  $F(1, 9) = 9.5, p < .02$ . Analysis of the same display trials revealed no significant difference between the element (858 ms) and configural (880 ms) conditions,  $F(1, 9) < 1$ . Search times in both the element and the configural conditions were significantly faster than in the separated condition on both different (1,446 ms) and same (1,388 ms) trials,  $F_s(1, 9) > 6.0, p_s < .05$ . There was no main effect or interaction with stimulus size in these analyses.

The positional stimulus set also showed a configural superiority effect (see Figure 4B). Analyses of these stimuli set found that search times in the configural condition (872 ms) were signifi-

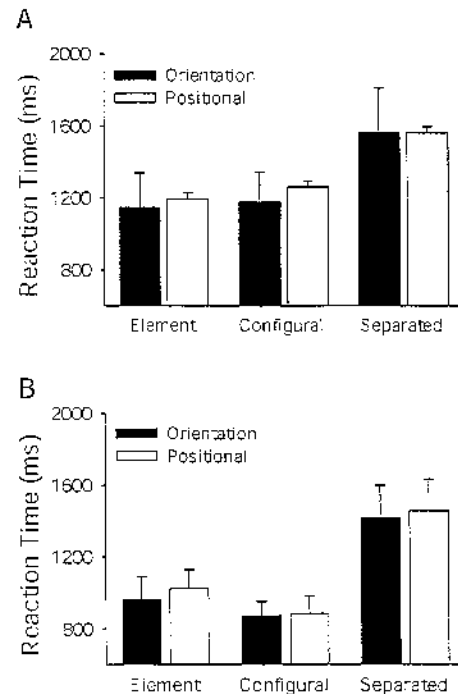


Figure 4. Humans' average reaction time (mean of same and different search times) for the texture (A) and geometric (B) displays used in Experiment 3. Error bars represent standard errors of the sample means.

cantly faster than in the element condition (1,166 ms) on different trials,  $F(1, 9) = 19.7, p < .01$ . Analysis of the positional stimuli for the same displays showed no significant difference between the element (899 ms) and the configural (882 ms) conditions,  $F(1, 9) < 1$ . Search times for the element and the configural conditions were significantly faster than in the separated condition on both different (1,504 ms) and same (1,388 ms) trials,  $F_s(1, 9) > 12.0, p_s < .01$ . There were no effects of interaction with stimulus size, except for a significant main effect during the comparison between the element and the separated conditions,  $F(2, 18) = 3.8, p < .05$ .

For the texture displays (see Figure 4A), analysis of the orientation stimulus set found that the configural condition (928 ms) was not significantly faster than the element condition (1,097 ms) on different display trials,  $F(1, 9) < 2$ . There was also no significant difference on the same display trials (configural = 1,394 ms; element = 1,194 ms) for these conditions,  $F(1, 9) < 2$ . Responses in both the element and the configural conditions were significantly faster than for the separated condition for the different display trials (1,519 ms),  $F_s(1, 9) > 9, p < .03$ , but not for the same display trials (1,638 ms),  $F(1, 9) < 2$ .

Analyses of the texture positional stimulus set showed no significant difference between the configural condition (1,076 ms) and the element condition (1,198 ms) for different display trials,  $F(1, 9) < 1$ . The same display trials also showed no significant difference (configural = 1,465 ms; element = 1,314 ms),  $F(1, 9) < 1$ . Further, the separated condition did not differ from either the element or the configural conditions for either the different display trials (1,248 ms) or the same display trials (1,638 ms),  $F_s(1, 9) < 1$ , and  $F_s(1, 9) < 2$ , respectively.



### Discussion

The human participants showed configural superiority effects for both the orientation and positional stimulus sets when tested with the geometric displays. That is, they showed faster discrimination reaction times when the discriminative features were embedded in a redundant context than when they were presented alone, indicating the humans were using the emergent features in the configural stimuli to facilitate their discrimination in some manner. That such emergent features due to line grouping or proximity are critical is further supported by the results with the separated condition. In this case, the spatial separation of the critical features and the context reduced or eliminated the emergent features and caused a considerable degradation in humans' performance. In one sense, separating the elements caused the humans to behave more like the pigeons in that having the added line context served only to interfere, rather than facilitate, the discrimination.

The texture displays did not produce the same configural superiority effect as observed with the geometric displays. This result is not surprising given some previous results with humans. Pomerantz and colleagues have found that for humans the role of emergent features and stimulus features, such as line-slope differences, are different for tasks involving form perception and displays more similar to our geometric displays than for denser texture-like displays (Pomerantz, 1981; Pomerantz & Pristach, 1989; see also Julesz, 1975, 1981).

Overall, our results with humans replicate those previously found in studies of human perception and performance. This indicates that the stimuli and task used in these studies are functionally capable of producing a configural superiority effect.

### General Discussion

In these experiments, we found that adding contextual information to a line discrimination task alters this discrimination in fundamentally different ways for humans and pigeons. In humans, the added context facilitated the discrimination of these features in displays that relied on form perception. In pigeons, the addition of the same context degraded their line orientation discrimination of the same stimuli.

Overall, our results are consistent with those reported by Donis and Heinemann (1993), showing that the role of contextual information differs for humans and pigeons. The current investigation substantially furthers our knowledge and confidence about the domain over which this difference extends. First, the pigeons consistently showed a configural inferiority effect with the orientation stimulus set regardless of the amount of experience with that set. We found an effect whether the pigeons had a very large amount of experience with the stimuli as in Experiment 1 or had far less experience with the stimuli as in Experiment 2. Further, this configural inferiority effect was exhibited across considerable changes in the organization of the display types (texture vs. geometric) and the overall size of the stimulus elements and in two separate groups of pigeons. Finally, if the pigeons were showing any sensitivity to the emergent features of the configural stimuli, one would have expected that performance with the separated condition would have been lower relative to the configural condition, exactly as it was in humans. This was not the case for the

pigeons. Taken together, these new results suggest that the added line segments in the configural condition only function to prevent the pigeons from seeing the critical oblique features, and the emergent features, so useful to the humans, are not available to the pigeons. These results suggest a true difference in how line segments are perceptually processed by birds and humans.

Several other comparative investigations of feature processing by pigeons and humans have also found potential processing differences between the two species. Allan and Blough (1989), for example, found that pigeons and humans differ as to the degree and pattern of search asymmetries exhibited in a visual search task. Treisman and Gormican (1988) have argued that such search asymmetries are diagnostic as to the type and organization of features used in early visual processing. Kelly, Bischof, Wong-Wylie, and Spetch (2001) have found that pigeons and humans also respond differently in detecting different types of Glass patterns. Delius and Hollard (1995) have found that pigeons and humans differ with regard to effects of the rotation in a matching discrimination, with pigeons showing little evidence of needing to use "mental rotation." Finally, Sekuler, Lee, and Shettleworth (1996) and Fujita (2001) have found that pigeons fail to show much evidence for the perceptual completion of partially hidden objects in several types of tasks. The current results join these prior results in suggesting that there are likely fundamental differences in how pigeons and humans process and group different types of visual features.

The exact influence of the context with the positional stimulus set was less clear. Humans showed enhanced discrimination in the geometric conditions with these stimuli. The pigeons showed a similar superiority effect in Experiment 1 and a similar, but non-significant, trend in Experiment 2. The extensive experience of the pigeons in Experiment 1 may have contributed to this difference. Regardless, these results suggest that with the right combination of features pigeons may also benefit from the addition of a configural context under some circumstances. Any final conclusion, however, will have to wait on further testing that can better establish the existence of any such configural superiority effect in pigeons and the conditions under which that effect may exist.

Overall, the examination of configural effects in humans has been an important source of information about the nature of the perceptual process, and this is true for pigeons as well. In the present case, this examination suggests that the nature of pigeons' perceptual processing is different in some way from humans' perceptual processing. The exact source of the growing number of studies supporting such a difference has yet to be isolated. Although no evidence in the present study rules out a dual-encoding account of the configural superiority and inferiority effects established here, given the above studies in which verbal labeling seems less of an issue, our current bias is toward the notion that the key difference between pigeons and people lies in the neural organization of the perceptual processing of line segments and their higher order grouping by each species. We hope future research will be able to draw together both physiological and behavioral observations from each species that will better illuminate this possibility. Establishing how the perceptual processes of pigeons (birds) and people (primates) are the same and different will remain a rich theoretical and empirical area for psychological inquiry for some time to come.



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