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Shape oddity recognition by pigeons is independent of shape orientation

El reconocimiento de las diferencias entre formas es independiente de la orientación de los mismos

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ABSTRACT

Pigeons that had been trained to perform in a conditional oddity-from-sample discrimination paradigm using one collection of stimuli were tested for transfer of performance with novel sets of stimuli. In these tests the orientation of sample and comparison shapes differed by 0°, 90°, 180° and 270°. The pigeons showed transfer at a high level of accuracy. They were not affected in their performance by the degree of orientation disparity between sample and comparison patterns.
DESCRITORS: Invariance, pattern recognition, pattern orientation, conditional discrimination, oddity-from-sample.

RESUMEN

Se estrenó a pichones a responder en un paradigma discriminativo condicional de diferencia de la muestra, empleando un conjunto de estímulos, y probando la ejecución en transferencia con un grupo de estímulos nuevos. En estas pruebas la orientación de la muestra y de las formas de comparación difirió en 0, 90, 180 y 270 grados. Los pichones mostraron transferencia con un alto nivel de precisión. Su ejecución no se vio afectada por el grado de disparidad en orientación, entre los patrones de muestra y los de comparación.
DESCRIPTORES: Invarianza, reconocimiento de patrones, orientación de patrones, discriminación condicional, diferencia de la muestra.

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The capacity to recognize objects independently of their orientation is frequently demanded of visual systems. From designers of artificial visual systems it is known that the information processing required to achieve this in real time is quite massive (Glünder, 1986). Indeed, items measuring orientation invariant shape recognition abilities are part of several human intelligence tests (Guilford and Hopfner, 1971). Pigeons, though highly visual animals, have a very small brain (about 2 ml). The question is whether they have enough computing power to implement an orientation invariance. Rather surprisingly Hollard and Delius (1982; see also Delius, 1985; Delius and Hollard, 1987; compare Emmerton, 1986) reported that a particularly difficult orientation invariance problem involving the discrimination of mirror-image patterns was solved better by pigeons than by humans. In humans this task yields increasing error rates and/or reaction times as the angular orientation disparities between the patterns to be discriminated increases. It is said to requiere a mental rotation of stimulus images (Shepard and Cooper, 1982). Pigeons, however, were found to yield constant and short reaction times with low and steady error rates independent of the orientation of the test patterns. These results indicating a superior orientation invariance performance by pigeons have met with some disbelief (Herrnstein, 1985; Cerella, 1987).

The present paper reports an independent set of data on orientation invariant pattern recognition in pigeons. The experiment was one within a series that examined the performance of pigeons in several different invariance problems (Lombardi and Delius, 1987a; 1987b). It employed an oddity-from-sample procedure which included transfer tests to novel stimulus combinations. Therefore it also tested whether pigeons can learn to operate a conditional discrimination on the basis of a relational identity/oddity rule (Carter and Werner, 1978). Despite positive evidence to this effect (e.g. Macphail, 1982; Lombardi, Fachinelli and Delius, 1984; Lombardi, Delius and Hollard, 1986) the pigeon's ability to do so continues to be doubted by some authors (e.g. Mackintosh, 1983; D'Amato, Salmon, Loukas and Tomie, 1986).

METHOD

Nine homing pigeons (Columbia livia) of local origin were employed. They had extensive previous experience with an oddity-from-sample task involving many different three-stimulus sets, (Lombardi, Fachinelli and Delius, 1984; Lombardi and Delius, 1988). They lived in individual cages and were kept at 85% of their free feeding weight throughout the experiment.

A Skinner box with 3 translucent keys arranged in a row (7 cm apart,

20 cm above the floor) was employed. An electromagnetic food-hopper was located under the central key 7 cm above the floor. The rear of each key was equipped with an electromagnetic shutter. An automatic projector taking special slides projected 3 stimulus patterns upon the keys from behind when the shutters were open. The white figures appearing on the dark 25 mm diameter keys, were all just inscribable in an imaginary 10 mm diameter circle. The apparatus was controlled by a computer that also recorded the subjects' responses.

Daily sessions (except weekends) consisted of 40 trials. A trial began with the sample shape being displayed on the central key. Fifteen pecks exposed the two comparison shapes on the side keys. One of these shapes was identical to the sample, the other was different from it. In successive trials the right/left side key allocation of identical/different comparisons alternated quasi-randomly (Fellows, 1967). Five consecutive pecks on a given side key shut off all 3 stimuli. Also in half of the trials, pecks directed to the "odd" comparison shape led to 3 sec access to food, while pecks to the "same" comparison shape led to 3 sec of darkness. The remaining trials were not reinforced, 5 consecutive pecks on either side key led directly to the intertrial interval (8 sec) that preceded all trials, and that included an advance to the next slide. Reinforced and non-reinforced trials followed each other quasi-randomly. The partial reinforcement scheme was intended to prepare the subjects for later transfer trials under extinction. In all trials the time that elapsed between the onset of the stimuli on the side keys until the first peck on one of these keys was recorded as the reaction time.

Since the pigeons were experienced they only needed to be retrained/habituated for 7 sessions. Combinations of 3 stimuli each (sets) constructed from the 15 patterns illustrated in Fig. 1, and with which the subjects had extensive previous experience, were used for retraining. 24 such stimulus sets were chosen randomly for a given session, taking care that both the odd-shape/right-key and odd-shape/left-key versions of any particular shape combination were included. This latter condition incidentally applied to all the stimulus set collections used in the experiment. Examples of these sets are shown in Fig. 1.

Additional to the training trials were 16 habituation trials per session. The purpose of these trials was to adapt the pigeons to shapes in different orientations. The sets for these trials were randomly selected among those assembled from 5 patterns known to the pigeons in the 0° orientation from an experiment run about 2 months previously. All three shapes constituting a given habituation set had the same orientation (0°, 90°, 180° or 270°), thus no orientation invariance was required at this stage (Fig. 1). The sequence of training and habituation sets within a session was determined by chance.

During the first few retraining/habituation sessions the response ratio requirements within trials were reduced, all trials were followed either by grain or time-out, and a correction procedure (trial repetition) followed incorrect

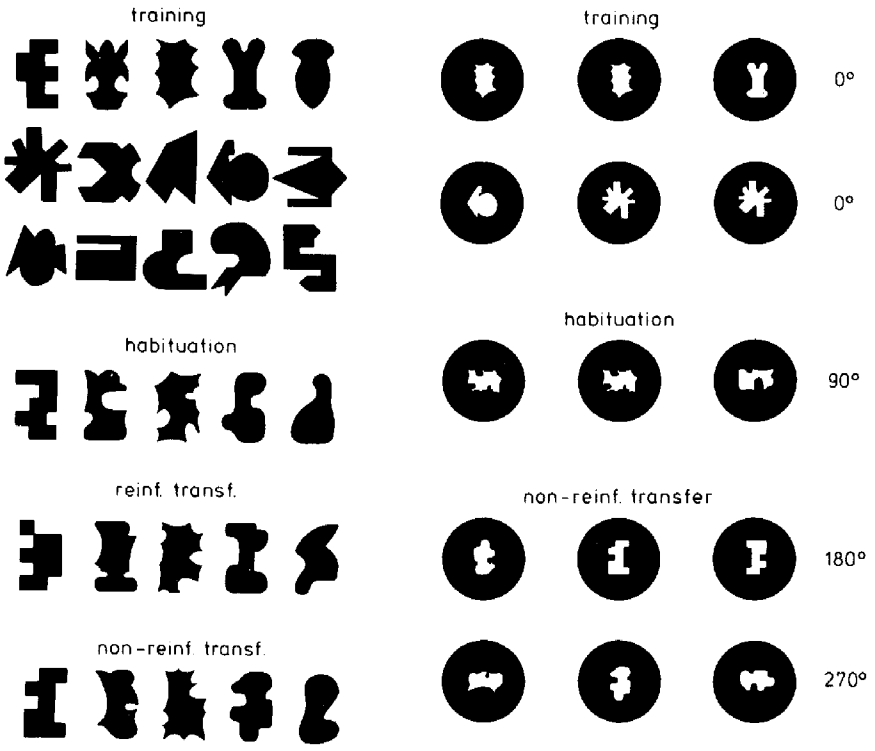

Fig. 1. Shapes employed (left) and examples of stimulus sets (right) used for the different components of the experiment.

trials. As performance improved these aids were gradually dropped and the two last sessions were run with full response ratios, no correction trials and non-reinforced trials, as described earlier.

The transfer phase lasted 10 sessions. Each incorporated 16 training trials and 8 habituation trials. The sets used were randomly selected from among those used in the previous phase. The remaining 16 trials were transfer trials. Eight of these were reinforced, the other 8 non-reinforced. The transfer trials were inserted randomly among the training/habituation trials but avoiding the first 3 and last 3 trials of a session. Two collections of 40 stimulus sets constructed from two separate groups of 5 patterns (Fig. 1) were presented twice over the 10 sessions. The patterns were known to the pigeons, but only in the 0° orientation, from the experiment run about 2 months previously. One collection was employed in reinforced transfer trials, the other collection was used in non-reinforced test trials. The sample shapes of all transfer sets were shown at the standard 0° orientation but both comparison patterns of a given set were either shown at a 0°, 90°, 190° or 270° clockwise orientation (Fig. 1). Within the 2 collections each shape appeared equally

often (8 times) as a sample, as a matching and as an odd stimulus. As comparisons each appeared 4 times in each of the 4 orientations, twice as odd stimulus (once right, once left), twice as matching stimulus (once right, once left).

RESULTS

The average percent correct trials, computed separately for the retraining/habituation and the two transfer components, are shown plotted session by session in Fig. 2. Since the birds were experienced they started at a high level of performance. The relative drop during the second session is explained by an incidental one month pause that intervened. There was little difference between the training and habituation components (mean over the 7 training/habituation sessions 97% and 96% correct trials respectively).

The pigeons' mean performance on the transfer trials incorporating orientation disparities between sample and comparison is shown separately for reinforced sets and non-reinforced sets. It was well above chance 50% on both components (mean over 10 sessions respectively 92% and 93% correct trials). It is notable that the performance on the reinforced component did not improve over the 10 transfer sessions. The mean performance on the non-reinforced transfer sets represent the true size-invariance test results. Each of the 9 birds performed significantly above chance on this component (binomial tests on choice proportions, all birds $p < 0.01$).

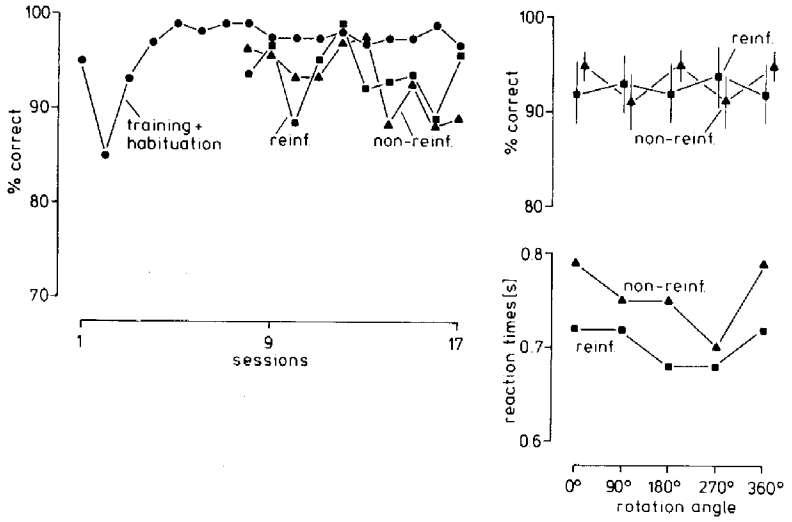

Fig. 2. Learning curves (left) and orientation dependance of discrimination performance (right). The various components (see text) are plotted separately. The data points corresponding to 360° are simply a repetition of the data points belongint to 0°.

Fig. 2 also shows the mean error rates and the median reaction times associated with each angular orientation disparity (clockwise) between sample and comparison stimuli. Friedman's analyses of variance revealed that neither variable is significantly affected by the orientation differences ($p > .05$). The pigeons made few errors (on average 7.5%) and responded fast (on average 0.75 sec) regardless of the orientation mismatch of sample and comparison patterns. The difference between the reaction times pertaining to the reinforced and non-reinforced components is just significant ($p = 0.05$).

DISCUSSION

The results are in agreement with those reported by Hollard and Delius (1982). They found that pigeons would transfer both matching to sample and oddity from sample performance upon stimulus sets made up from novel shapes and with orientation disparities of 0°, 45°, 90°, 135° and 180° clockwise between sample and comparison shapes. The subjects evinced constant response accuracies and speeds regardless of the degree of orientation misalignment. The same results obtained here again, pigeons transfering oddity-from-sample performance onto stimulus sets and with orientations disparities of 0°, 90°, 180° and 270° tested in extinction. The animals in both studies had no previous experimental experience with orientation invariance tasks.

The odd shapes in Hollard and Delius (1982) experiment were mirror-images of the sample patterns. In the present experiment the odd patterns were always arbitrarily different shapes. In pigeons both kinds of stimuli obviously yield a closely comparable performance (see also Delius, 1985). In humans the two conditions produce quite different results. Mirror-image patterns discriminations yield the mental rotation effect mentioned earlier while arbitrary patterns do not (White, 1980, but see Joliceur, 1984). With arbitrary comparison patterns the performance of pigeons and humans is in fact quite similar.

It is inviting to ascribe the orientation invariance that we describe to a stimulus generalization along the orientation dimension. Lombardi and Delius (1987 a) have argued, in the context of size invariance, that even though such an ascription is reasonable at the descriptive level, it has problems if it is meant as an explanation. In the particular instance of orientation invariance there is a striking lack of congruence between our data and response gradients measured in conventional orientation generalization tests. These generally reveal response decrements with orientation disparities of 90° or less (Honig and Urcuioli, 1981). The present results imply virtually flat gradients over the full range of 360°. Note though that the oddity-from-sample paradigm with both comparison stimuli equally misaligned forces the subjects to disregard orientation as a cue. The optional nature of orientation invariant behaviour during pattern discrimination by pigeons is also stressed by Lohmann, Delius, Hollard and Friesel (1987) on the basis of other experimental evidence.

It is remarkable that the performance on reinforced and non-reinforced transfer sets was quite similar, the latter in fact producing liminally worse reaction times. It suggests that a performance improvement due to explicit conditioning to specific stimulus configurations is rather slow in having an effect in this situation. This fact can also be deduced from the extended training that the animals required to acquire the initial oddity-from-sample task (Lombardi, Fachinelli and Delius, 1984).

Finally, the results of the present experiment demonstrate again that given a propitious experience pigeons can transfer an oddity-from-sample relational rule that they learned with one collection of stimulus sets to newly configured stimulus sets. They further support the analogous conclusions reached by Lombardi et al. (1986) after review of the then extant evidence.

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REFERENCES

Carter, D.E. and Werner, T.J. (1978). Complex learning and information processing by pigeons: A critical analysis. *Journal of the Experimental Analysis Behaviour, 29,* 565-601.

Cerella, J. (1987). Shape constancy in the pigeon: the perspective transformation descomposed. In: M.L. Commons, S.M. Kosslyn and R.J. Herrnstein (eds.) Pattern Recognition and Concepts in Animals, People and Machines. Hillsdale, Erlbaum (in press).

D'Amato, M.R., Salmon, D.P., Loukas, E. and Tomie, A. (1986). Processing of identity and conditional relations in monkeys (Cebus apella) and pigeons (Columba livia). *Animal Learning and Behavior, 14,* 365-373.

Delius, J.D. (1985). Complex visual information in the pigeon. In: V.D. Ilyichev, V.M. Gavrilov (eds.) Acta XVIII Congressus Internationalis Ornithologici, Moscow: Nauka, pp. 804-810.

Delius, J.D. and Hollard, V.D. (1987), Orientation invariance of shape recognition in forebrain-lesioned pigeons. *Behavioural Brain Research, 23,* 251-259.

Emmerton, J. (1986). The pigeon's discrimination of movement patterns (Lissajous figures) and contour-dependent rotational invariance. *Perception, 15,* 573-588.

Fellows, B.J. (1967). Chance stimulus sequences for discrimination tasks. *Psychological Bulletin, 67,* 87-92.

Glünder, H. (1986). Neural computation of inner geometric pattern relations. *Biological Cybernetics, 55,* 239-251.

Guilford, J.P. and Hoepfner, R. (1971). The Analysis of Intelligence. New York: Mac Graw-Hill.

Herrnstein, R.J. (1985). Riddles of natural categorization. *Philosophical Transaction of the Royal Society London, B. 308,* 129-144.

Hollard, V.D. and Delius, J.D. (1982). Rotational invariance pattern recognition by pigeons and humans, *Science, 218,* 804-806.

Honig, W.K. and Urcuioli, P.J. (1981). The legacy of Guttman and Kalish (1956). Twenty five years of research on stimulus generalization. *Journal of the Experimental Analysis of Behavior, 36,* 405-445.

Joliceur, P. and Landau, M.J. (1984). Effects of orientation on the identification of simple visual pattern. *Canadian Journal of Psychology, 38,* 80-93.

Lohmann, A., Delius, J.D., Hollard, V.D. and Friesel, M.F. (1987). Discrimination of shape reflections and shape orientation by pigeons. *Journal of Comparative Psychology,* in press.

Lombardi, C.M. and Delius, J.D. (1987a). Size invariance in visual pattern recognition by pigeons. In M.L. Commons, S.M. Kosslyn and R.J. Herrnstein (eds.) Pattern Recognition and Concepts in Animals, People and Machines. Hillsdale: Erlbaum, (in press).

Lombardi, C.M. and Delius, J.D. (1987b). Pattern recognition invariance in pigeons: Outline, color and contrast. (in prep.).

Lombardi, C.M., Fachinelli, C.C. and Delius, J.D. (1984). Oddity of visual patterns conceptualized by pigeons. *Animal Learning and Behaviour, 12,* 2-6.

Lombardi, C.M., Delius, J.D. and Hollard, V.D. (1986). Conceptualización de una relación lógica en palomas. *Revista Latinoamericana de Psicología, 18,* 277-297.

Mackintosh, N.J. (1983). Conditioning and Associative Learning. Oxford: Clarendon.

Macphail, E. (1982). Brain and Intelligence in Vertebrates. Oxford: Clarendon.

Shepard, R.N. and Cooper, L.A. (1982). Mental Images and their Transformations. Cambridge, Mass.: MIT Press.

White, M.J. (1980). Naming and categorization of tilted alphanumeric characters do not require mental rotation. *Bulletin of the Psychonomic Society, 15,* 153-156.