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Global-feature classification can be acquired more rapidly than local-feature classification in both humans and pigeons

Abstract When humans process visual stimuli, global information often takes precedence over local information. In contrast, some recent studies have pointed to a local precedence effect in both pigeons and nonhuman primates. In the experiment reported here, we compared the speed of acquisition of two different categorizations of the same four geometric figures. One categorization was on the basis of a local feature, the other on the basis of a readily apparent global feature. For both humans and pigeons, the global-feature categorization was acquired more rapidly. This result reinforces the conclusion that local information does not always take precedence over global information in nonhuman animals.

Keywords Visual perception · Global–local processing · Gestalt perception · Categorization · Pigeons

Introduction

Humans have a remarkable ability to integrate configural information from elemental parts, indeed global information often takes precedence over local information. For example, in Navon's experiments (Navon 1977, 1981, 1983), people were shown collections of a particular letter arranged to form a global configuration that was also a letter (e.g. an "H" made up of "S"s). Identification responses were faster for the global configurations than for the local letters. Moreover, the identification of global letters was not influenced by local letters, whereas the identification of local letters was significantly slower when the global letter was inconsistent with local letters.

Using similar stimuli, Cavoto and Cook (2001) examined whether global information also takes precedence in

pigeons. They trained their subjects to discriminate stimuli that only differed at a global level (e.g. a "T" consisting of "O"s vs an "N" consisting of "O"s), and to discriminate stimuli that only differed at a local level (e.g. an "O" consisting of "T"s vs an "O" consisting of "N"s). The pigeons given the local-letter discrimination acquired the task more readily than the pigeons given the global-letter discrimination. This local precedence effect was further supported by the results of the "conflict" tests. After the pigeons acquired the discrimination of letters at global and local levels on a binary choice task (e.g. P is assigned for the left key as a correct response, and X is assigned for the right key as a correct response), pigeons were tested with the stimuli which had conflicting contingencies (e.g. P consisting of Xs and X consisting of Ps). They found that the pigeons made the local-letter choice more than global-letter choice when the global and local letters were conflicted.

Fagot and his colleagues (Fagot and Deruelle 1997; Deruelle and Fagot 1998; Fagot and Tomonaga 1999) reported that baboons and chimpanzees also show a local precedence effect. In their "odd-one-out" visual search experiments, baboons and chimpanzees were trained to find an odd item at either a global level (circular arrangement or square arrangement of local elements) or a local level (circles or squares). Both the baboons and the chimpanzees found the target more quickly and accurately with local element odd items, whereas humans showed an advantage at the global level. In nonhuman primates, the local-feature tendency became more pronounced when the global features consisted of fewer local elements.

Local-feature precedence has also been reported in tufted capuchin monkeys using a simultaneous identity matching-to-sample procedure (Spinozzi et al. 2003). The stimuli were designed to be hierarchical using four distinctive shapes: circles, squares, rhombi, and the letter X, at global and local levels, and the monkeys were required to judge which of two comparison stimuli was identical to the matching stimulus. The capuchin monkeys showed higher accuracy when the matching target was a local element (e.g. a circle consisting of squares and a rhombus consist-

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ing of squares) than when the target was the global configuration (e.g. a square consisting of circles and a square consisted of rhombi).

The results discussed thus far might be taken as evidence for a general difference in visual processing between human and nonhuman organisms, global information taking precedence in the former and local information taking precedence in the latter (see e.g. Cerella 1980; Kelly et al. 2001, for arguments of this type). On the other hand, the local-feature precedence observed in these studies may result from the specific stimuli and procedures employed. For example, pigeons are known to generalize more effectively to shapes smaller than the training items than to shapes larger than the training items (Lombardi and Delius 1990). With a hierarchical design of stimuli like that used by Cavoto and Cook (2001) this phenomenon could, in itself, produce the appearance of a local precedence effect.

The fact that Cavoto and Cook (2001) used a touch screen to detect responses might have also precluded them from finding a global precedence effect. This is because, in humans at least, the effect is only found for relatively small stimuli (Kinchla and Wolfe 1979), whilst the stimuli in Cavoto and Cook's study subtended a large visual angle (about 20°, according to our estimation from their description of apparatus and stimuli) at the point of response. A similar argument may be made about the density of stimuli, which also biases attention to the global level. For example, Hopkins and Washburn (2002) found that chimpanzees show global precedence (higher accuracy and shorter response time) in a task employing hierarchical stimuli and a sequential matching-to-sample procedure. Why might global precedence have been observed in this study whilst Fagot and Tomonaga (1999) observed local precedence with the same species? One possibility is that the difference is attributable to differences in the density of local elements, factors known to affect the recognition of global patterns in nonhuman primates (Fagot and Tomonaga 2001), as well as in humans (Kimchi and Palmer 1985; Kimchi 1988).

There is also evidence that suggests pigeons may show global precedence under certain conditions. For example, Fremouw et al. (1998) tested pigeons with Navon-type hierarchical stimuli and demonstrated that they showed faster and more accurate responding to global features when the global-feature discrimination occurred more frequently than local-feature discrimination within a session, and vice versa. Fremouw et al. (2002) further demonstrated that pigeons' attentional shift between wholes and parts can be controlled by priming cues, specifically the brief presentation of a color signal before the trial that indicates whether the target is at the global or local level.

In summary, humans show global-feature precedence if certain stimulus conditions are met. There is also evidence that some other primates show global-feature precedence if similar stimulus conditions are met. Pigeons also appear able to utilize global information at the expense of local information, if the global information is more likely to predict reinforcement. Nevertheless, Cavoto and Cook's (2001)

study suggests that pigeons attend to global information less readily than they attend to local information, whilst the reverse is sometimes true for humans (e.g. Navon 1977).

There are at least two possible accounts of this difference between pigeons and humans. One possibility is that it reflects a general species difference – people sometimes show global precedence whilst pigeons simply do not. Another is that pigeons, like humans, only show global precedence for certain stimuli and that Cavoto and Cook's stimuli do not fulfil those conditions. The present experiment is an attempt to provide evidence for the latter position. Hierarchical stimuli were not used because of the concern about differential generalization to objects of different relative size, noted previously. Our stimuli were also designed to subtend a relatively small visual angle because, as previously discussed, using large stimuli is likely to preclude the possibility of finding a global precedence effect. We also attempted to maximize the chances of finding global precedence by using stimuli where the global features appeared (to us) more salient than the local features.

Our test of global precedence was to compare the speed of acquisition of two different categorizations of the same four geometric figures. One categorization involved dividing the set of four stimuli on the basis of a local feature whilst the other, orthogonal, categorization involved dividing them on the basis of a highly salient global feature. The manipulation was between-subjects, and we tested two different species – humans and pigeons. Global precedence would be indicated by faster acquisition of the global-feature categorization than the local-feature categorization.

Methods

Subjects

Pigeons

Fourteen pigeons from local fanciers were used as subjects. Each bird was maintained at or over 90% of its free-feeding weight throughout the experiment by the delivery of hemp and conditioner during the experimental sessions and by supplements of mixed grain on other occasions. The pigeons were usually housed in two indoor aviaries, each measuring 2.2×3.4×2.4 m. The aviary was equipped with pigeonholes in units of 16 and ad-lib access to water and crushed oyster shells was available. They were moved to individual cages at least 30 min before testing. The birds were maintained on a 12:12 h light/dark cycle, with 30-min simulated dawn and dusk periods.

Humans

Fourteen university students were voluntarily recruited from the University of Exeter. All subjects had normal or corrected-to-normal vision. The subjects ranged in age from 21 to 36 years.

Apparatus

Pigeons

Two identical three-key operant chambers, 690×490×390 mm, were used. Each consisted of a plywood box, with a three-key in-

telligence panel (Campden Instruments, London, UK), 335×350 mm, mounted centrally into the front wall. The three keys were each 25 mm in diameter, and were mounted 105 mm apart and 240 mm above the grid floor of the chamber. The two side keys were translucent, while the center key was transparent, and had a shutter operated by a rotary solenoid situated behind it, so that viewing of a computer monitor (CM1414E, Opus Technology), 150 mm behind the center key, was prevented during the intertrial intervals. A 70×75 mm aperture was positioned 150 mm below the center key, giving access to a solenoid-operated food hopper containing a 1:2 mixture of hemp and conditioner. The availability of this food was signaled by a 1.0-W white light in the hopper aperture, operated when the hopper was presented. General illumination was given by a 3.5-W yellow-lensed houselight situated 120 mm above the center key. Masking noise was provided by white noise relayed via a 35-Ω loudspeaker mounted on the back of the intelligence panel. A separate PC-compatible computer was used to generate the experimental stimuli for each test chamber. Both chambers and their stimulus generation computers were housed in a darkened testing room. All other equipment was outside this room. A further PC-compatible microcomputer controlled and recorded all experimental events and responses; a network link enabled this computer to instruct the computers attached to the experimental boxes to generate the stimuli. Each bird was assigned to a single test chamber for all stages of the experiment.

Humans

A PC-compatible laptop computer (Sony PCG-505 V) was used to control events of the experiment and to record participants' responses using E-prime (Psychology Software Tools).

Stimuli

The stimuli were four geometric figures each consisting of six components (Fig. 1). Stimuli A and B, and stimuli C and D, had identical components but they constructed different overall forms. On the other hand, stimuli A and C, and stimuli B and D, had identical global figures but their local components were not identical (e.g. C and D contain squares whilst A and B do not). The stimuli were
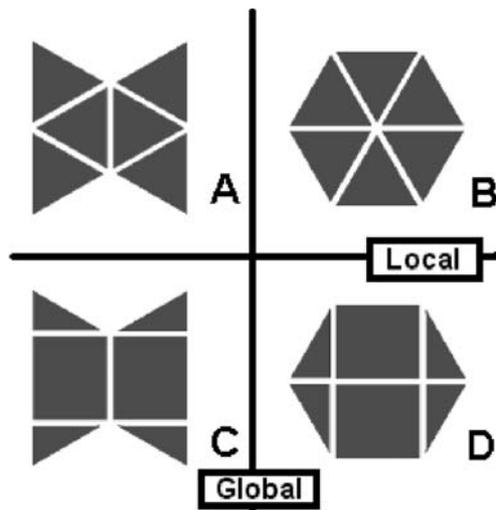
Fig. 1A–D Test stimuli. Each stimulus consists of six local components. Stimuli **A** and **B** and stimuli **C** and **D** have identical components but each pair have different global figures, whereas the global figures of stimuli **A** and **C** and stimuli **B** and **D** are same and the local components of them are different. These stimuli were displayed with red color on a black background

drawn in red on a black background, this color combination being selected in order to facilitate discrimination for the pigeons. For both species, the stimuli subtended approximately 4.6° of visual angle horizontally and 5.7° of visual angle vertically. The on-screen size of stimuli were 14×17.5 mm for pigeons and 40×50 mm for humans, whilst the viewing distances were approximately 175 mm and 500 mm, respectively.

Procedure for pigeons

Initial training

All pigeons were first given magazine training and then, using an autoshaping procedure, trained to peck the center key when the shutter was opened to reveal a plain white screen. After the acquisition of center key pecking, a fixed interval (FI) schedule was introduced and the value of the FI was gradually raised to 12 s. Observing key training followed, in which the bird was shaped to open the center shutter by pecking the right-side key when it was transilluminated with amber light. This observing key training was repeated for at least three sessions to stabilize the pigeons' behavior.

Discrimination training

Once the initial training was completed, the pigeons were arbitrarily assigned into two groups of seven birds and given successive discrimination training. Each session started with 3 s of presentation of the food hopper followed by an intertrial interval. Each trial began with pecking the observing key, which then opened the shutter to reveal a stimulus on the monitor. Pecks to the center key were counted but not reinforced during the first 10 s of each trial (fixed time; FT). Following the completion of the 10-s FT on positive stimulus trials, pecks were reinforced by a 3-s presentation of food hopper on a variable interval 4-s schedule; the trial ended after reinforcement. The negative stimulus trials ended immediately, without reinforcement, when the variable interval had elapsed. In the global group, stimuli A and C were positive and stimuli B and D were negative for four pigeons, and the contingency was reversed for the other three. In the local group, stimuli A and B were positive and stimuli C and D were negative for four pigeons, and the contingency was reversed for the other three. The intertrial interval varied randomly between 5 and 15 s.

A session consisted of 80 trials, divided into 10 blocks of 8 trials containing 4 positive and 4 negative trials. The order of the stimulus presentation was random with the constraint that no more than three positive or negative stimuli were presented consecutively. Typically, there was one training session a day, and six training sessions in a week.

Training was to criterion, with an upper limit of 15 sessions. Performance on each session was indexed by calculating the Rho (ρ) statistic of Herrnstein et al. (1976) for discrimination between each of two pairs of stimuli. These pairs were A–B and C–D for the local group, and A–C and B–D for the global group. The two ρ-values attained in this way were then averaged. Criterion was defined as meeting or exceeding an averaged ρ of 0.8 in two consecutive sessions.

Procedure for humans

The participants, who were tested individually, sat approximately 500 mm from the screen. They were tested in a single short session. In this session, the start of each trial was signaled by presentation of a small fixation cross for 500 ms, followed by the presentation of one of the four stimuli. Participants categorized the stimulus by pressing either the C key with the index finger of their left hand or the M key with the index finger of their right hand. As soon as a response was made, the stimulus was replaced with a 500-ms feedback message that read either "correct" or "incorrect". The computer then automatically moved on to the next trial. The
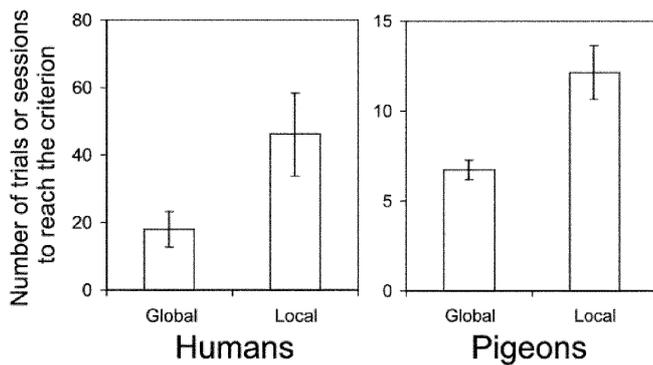
Fig. 2 *Left panel* Number of trials required to reach the criterion by human participants. The *bars* represent mean and *error bars* indicate the standard error. *Right panel* Number of sessions required to reach the criterion by pigeons. The *bars* represent the mean and *error bars* indicate the standard error

session continued until the participant had made either 10 consecutive correct responses or 80 responses in total. The number of trials required to attain the criterion was used as a measurement of the task difficulty and the reaction time was also recorded as a secondary measurement.

In the global group, the two categories were (A, C) and (B, D). In the local group, the two categories were (A, B) and (C, D). The M key was associated with A and C for four of the subjects in the global group and A and B for four of the subjects in the local group, whereas the C key was associated with A and C for three of the subjects in the global group and A and B for three of the subjects in the local group. A session was divided into ten blocks of eight trials containing four positive and four negative trials. The order of the stimulus presentation was random.

Results

Figure 2 presents the mean number of sessions required to reach the criterion for the pigeons and the mean number of trials required to reach the criterion for the humans. Pigeons in the global group required fewer sessions, and humans in the global group required fewer trials, to acquire the discrimination than those in the local group (Mann-Whitney $U_{7,7}=7$, $P=0.023$ for pigeons; $U_{7,7}=8$, $P=0.034$ for humans). The reaction time in humans did not differ significantly between the global group ($M=1.10$ s, SD= 0.49) and the local group ($M=1.57$ s, SD=0.97), $t(12)=1.146$, $P=0.274$.

Discussion

For both pigeons and humans, a categorization on the basis of a global feature was acquired more quickly than an orthogonal categorization of the same stimuli on the basis of a local feature. Hence, in contrast to Cavoto and Cook (2001), both species appeared to show a global-feature advantage, at least under our procedures.

What might lie behind the difference between our results and those of Cavoto and Cook (2001)? One possibility is the difference in effective visual angle of the stimuli.

Large visual angle is known to preclude a global precedence effect in humans (Kinchla and Wolfe 1979), and Cavoto and Cook's use of a touch screen would have meant that for their pigeons, the visual angle would have been relatively large at the point of response. In contrast, our stimuli were quite small, subtending less than 7° of visual angle.

Another possibility is that the difference in precedence is due to the density of local elements. Cavoto and Cook employed stimuli that were relatively sparse arrays of elements whilst in our stimuli the local elements were quite closely packed. High element density is known to promote the global precedence effect in humans (Martin 1979; Dukette and Stiles 2001), and it may be the case that a similar phenomenon occurs in pigeons.

A third possibility is that the difference is due to the relative difficulty of the local-feature discrimination in the two experiments. In Cavoto and Cook, the local-feature discrimination is between distinct letters, whilst in our study it is between collections of local features that are (perhaps) less distinct. For example, whilst one category contains squares and the other does not, all four stimuli contain multiple triangles. This sort of overlap would presumably result in considerable generalization between reinforced and nonreinforced stimuli, making our local-feature discrimination rather difficult (although still possible) to acquire. The close proximity of the local features to each other may have also increased the difficulty of the local-feature discrimination.

A last possibility is that the global/local precedence is due to the duration of the stimulus presentation. Cavoto and Cook (2001) demonstrated that two out of four pigeons dramatically shifted the proportion of global and local choices according to stimulus duration: pigeons actually made global choices when the duration of stimulus presentation was 5 s, whereas all the four pigeons made local choices when the duration was 0.50 s, 0.75 s, and 1.5 s. In the present experiment, the duration of stimulus presentation was over 10 s. This also seems to be a factor, which promotes pigeons' global precedence in the present experiment.

In conclusion, it is perhaps unlikely that any species or individual would always be dominated either by global or local features. Rather, it seems probable that the specific properties of the cues available at each level will influence the extent to which each comes to control behavior (Garner 1974, 1978; Grice et al. 1983). Our findings show that, for certain stimuli, both pigeons and humans demonstrate global-feature precedence. By comparison to Cavoto and Cook (2001), our findings also hint that some of the conditions required for global precedence in humans and pigeons may be broadly the same (e.g. small stimuli, high element density). Despite the considerable differences in physiology and evolutionary history, the study of comparative cognition may still have something to reveal about information processing commonalties among the vertebrates.

to the requirements of the UK Animals (Scientific Purposes) Act, 1986 and University and departmental guidelines. Departmental ethical requirements in respect of human participants were followed.

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