veloped at 12°C, the onset of calling behavior was advanced to 1.9 ± 0.9 hours after lights off (21 days of data from six females) (*11*). Pheromone release in the female is shifted so that it coincides with the flight time of similarly treated males. Thus, temporal coordination between the sexes is preserved because both partners respond in a complementary fashion to changing environmental temperatures.

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3. The activity-monitoring device consisted of a screen cage (~ 12-cm cube) which was mounted on the end of a 30-cm strip of thin spring steel. The end of the strip which was opposite to the cage was fastened to a support. The other end was attached to a wire contact that extended beyond the cage. When the cage moved, due to the activity of the moth inside, this wire touched an external fixed contact and thus completed a circuit which included an event recorder pen. The apparatus was set so that it recorded the gross movements due to flight but not the smaller movements involved in preflight warm-up. The activity patterns obtained from various species of moths were consistent with the field observations of the mating times of these species [P. Rau and N. L. Rau, *Trans. Acad. Sci. St. Louis* **26**, 82 (1929)].
4. The periods of adult development were days 1 through 7, days 8 through 13, and days 14 through 20. These stages were defined by changes in the developing animal which could be seen through the pupal cuticle. Day 1 of development was characterized by the retraction of the wing epidermis from the overlying pupal cuticle, day 8 by the appearance of brown pigmentation in the developing compound eye, and day 14 by the pale coloration of the facial scales. The time table of development was modified from C. M. Williams and P. L. Adkisson, *Biol. Bull.* **127**, 511 (1964).
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11. ———, personal communication. The female moths were illuminated with a dim red light during the scotophase of the photoperiod. Each animal was then checked for "calling" at approximately 1-hour intervals throughout the night.

12. This research was conducted at the Concord Field Station of Harvard University. I thank Prof. L. M. Riddiford, L. P. Lounibos, and an anonymous reviewer for helpful suggestions and for a critical reading of the manuscript. Supported by NSF grant GB-35540.

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Human Visual Ecology and Orientation Anisotropies in Acuity

Abstract. *The visual environment of Cree Indians from the east coast of James Bay, Quebec, is different from that of city-raised Euro-Canadians. So also are their corresponding orientation anisotropies in visual acuity. A Euro-Canadian sample exhibited the usual higher resolution for vertically and horizontally oriented gratings as compared with oblique orientations, while a Cree Indian sample did not. The most parsimonious explanation of these acuity differences is that orientation-specific detectors in humans are tuned by the early visual environment.*

Human visual acuity varies with stimulus orientation, being highest for lines oriented horizontally and vertically and poorest for lines oriented 45° to the left and right of vertical (*1, 2*). Furthermore, this orientation anisotropy is not produced by asymmetries in the dioptrics of the eye (*3*), and the neural origin of this effect is proximal to the origin of the electroretinogram (*2*).

Selective early visual experience of cats alters not only the perceptual but also the physiological responses of the visual system (*4*). Kittens raised in a visual environment consisting solely of vertical or horizontal stripes are functionally blind to orthogonally oriented contours, and no neurons in their visual cortices appear to be tuned to this orientation. That similar effects result from partial visual deprivation in humans has been suggested by studies (*5*) demonstrating that certain astigmatic subjects, after perfect optical correction, still exhibit a marked impairment in the resolution of contours in the plane of their astigmatism.

We present evidence here that the orientation anisotropy in visual acuity might also be the result of differential early visual experience. A sample of Euro-Canadians raised in a "carpentered" (*6*) environment, with its preponderance of vertical and horizontal contours, showed the usual anisotropic acuity pattern, while a Cree Indian sample raised in a traditional setting that presents a more heterogeneous array of contour orientations did not exhibit this effect.

The Euro-Canadian sample consisted of 20 university students (10 male and 10 female) from Kingston, Ontario. All subjects in this group were raised in and around typical North American houses and buildings, which provide a visual environment with a marked predominance of vertical and horizontal contours. The Cree sample consisted of 16 people (10 male and 6 female) from Wemindji, a small Indian village on the east coast of James Bay in northwest Quebec (79° longitude, 53° latitude). These subjects had all been raised in traditional housing, which alternated between a summer cook tent or *meechwop* (Fig. 1) and a winter lodge or *matoocan* (*7*). These structures, both internally and externally, present contours in virtually all orientations. Similarly, the taiga, consisting of coniferous trees, presents contours in many orientations. There are many horizontal and vertical contours in this environment (horizon, tree trunks, and so forth), but they do not predominate as they do in the carpentered environment. Cross-cultural data indicate that the spatial-perceptual abilities of both groups are high and comparable (*8*), and that both the Cree and English languages are rich in orientation-specific terms.

To measure orientation anisotropies in visual acuity, we constructed an apparatus that permitted a grating pattern to be rotated to various orientations. This device was constructed of Plexiglas and consisted of a white disk 10.5 cm in diameter surrounded by a black annulus 15.5 cm in outside diameter. The central disk was covered with a clear plastic sheet on which was printed a grid of black stripes 0.15 mm wide, with a spatial frequency of 15.75 line/cm (Letratone LT 70). A bolt mechanism with appropriately positioned holes permitted the experimenter to rotate and lock the grating pattern into either the horizontal, vertical, or left or right oblique orientations. The apparatus, mounted on a black wooden stand, was kept perpendicular to the surface of the table on which it was placed. To eliminate the need for verbal responses, we constructed a simple response indicator, which consisted of a white disk 10 cm in diameter with a black pointer mounted in the center and the four stimulus orientations marked at the circumference.

Subjects were seated in turn at one end of a 3.7-m table and instructed in their mother tongue how to respond to the stimuli. They were told to turn the black pointer of the response apparatus until it matched the orientation of the grating, after which several practice trials were given to check communication. Subjects were also informed that the lines would always be in one of four possible orientations, horizontal, vertical, or left or right oblique.

A modification of the descending method of limits was employed to measure relative visual acuities. On each presentation the orientation was set while the grating was shielded from the subject's view by a 25 by 38 cm sheet of cardboard. The stimulus was then exposed for 5 seconds, after which the subject's response to it was recorded. On the first trial the grating was initially 90 cm from the subject and was then moved back in successive 30-cm increments. At each distance the grating was presented twice in each of the four orientations, with order of presentation randomized. When a subject produced five or fewer correct responses (halfway between perfect discrimination and chance performance) at two consecutive distances, a second trial was initiated, with the grating 15 cm nearer the subject than the position where his first error occurred. The grating was again moved back in 30-cm increments until the same criterion of failure was reached. Then a third trial was started, with the grating 7.5 cm nearer to the subject than the position where his first error occurred on the second trial; however, this time the distance was increased in 15-cm steps. The experiment was terminated when the criterion of failure was reached on the third trial.

The mean visual acuities for each grating orientation for the Cree and Euro-Canadian groups are presented in Fig. 2. Although the experimental procedure was the same for the two groups, they were of necessity tested in different locations under somewhat different lighting conditions (however, the illumination was estimated to be in the range of 1400 to 1700 lu/m^2). Thus, a direct statistical comparison between visual acuities of the two groups is not justifiable. However, comparisons can be readily made between the two groups by contrasting their relative thresholds for different stimulus orientations.

To control for possible response biases of individual subjects, the raw data were corrected by dividing the number of correct responses each subject made to a particular orientation by the total number of times he used that particular orientation as a response. These corrected scores were then analyzed separately for each group by employing a one-factor repeated measures design (*9*), which indicated a significant difference between mean visual acuity scores for different orientations for the Euro-Canadian group ($F=5.48$; d.f. $=3$, 57; $P<.005$) but not for the Cree group ($F=1.77$; d.f. $=3$, 45; $P>.15$). If the variability within the Cree group were greater than that of the Euro-Canadians, this might have masked small variations in acuity with orientation. However, the subject-orientation error term used in this analysis of variance is smaller, although not significantly so ($F=1.056$; d.f. $=57$, 45) for the Cree group than for the Euro-Canadian group. Matched t-tests within the Euro-Canadian data reveal no significant differences in acuity for vertically or horizontally oriented gratings ($t=1.54$, d.f. $=19$, $P>.14$) or between left and right oblique orientations ($t=0.04$, d.f. $=19$, $P>.50$). However, the average of horizontal and vertical mean acuity scores was significantly higher than the average for the two oblique orientations ($t=3.13$, d.f. $=19$, $P<.007$). Although there was no significant effect of stimulus orientation for the Cree group, similar matched t-tests were calculated for this sample. These yielded no significant differences for the same three comparisons (*10*).

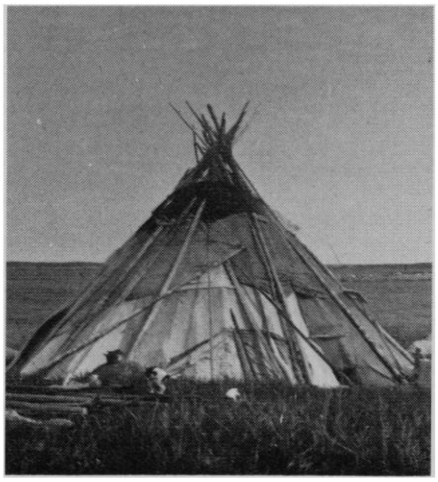

Fig. 1. A Cree Indian summer cook tent or *meechwop* at Wemindji, a small Indian village on the east coast of James Bay, Quebec. These structures, along with the Cree winter lodges or *matoocan*, present contours in virtually all orientations. In contrast, the carpentered environment produced by a high density of typical urban houses and buildings presents a preponderance of vertical and horizontal contours. The differences in contour orientation frequencies are correlated with differences in orientation anisotropies in visual acuity for grating patterns.

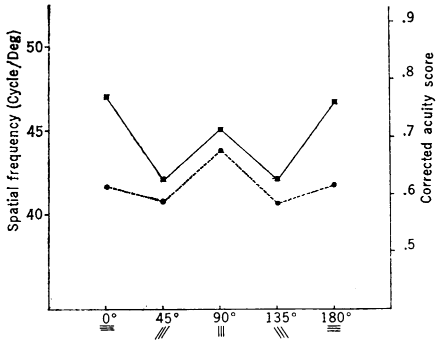

Fig. 2. Visual acuity for gratings as a function of line orientation for Cree Indians (circles) and Euro-Canadians (squares). A significant effect of stimulus orientation was obtained for the Euro-Canadian group ($F=5.48$; d.f. $=3$, 57; $P<.005$) raised in a carpentered environment, but not for the Cree group ($F=1.77$; d.f. $=3$, 45; $P>.15$) raised in a visual environment with a more heterogeneous array of contour orientations.

Thus, the Euro-Canadian subjects raised in a carpentered environment exhibit an orientation anisotropy of visual acuity similar to that reported previously. That is, they show higher acuity for grating patterns presented in the horizontal and vertical orientations than in oblique orientations. In contrast, the Cree group, raised in a more heterogeneous visual environment, did not show the same orientation anisotropy in acuity. These results are consistent with the notion that differences in the frequency of various contour orientations in the early visual environment of humans produce corresponding orientation differences in visual acuity in later life.

However, in a cross-cultural study of this nature many uncontrolled concomitant variables might result in similar orientation anisotropies. For example, it could be argued that the two samples interpreted the test situation differently and that this produced the orientation effect. However, this seems unlikely because the groups did not differ significantly in terms of the subject-orientation interaction and both groups made approximately the same number of errors. Alternatively, systematic differences in ocular astigmatism between the two groups might be invoked to explain the differences in orientation anisotropy. However, many arguments rule out this possibility. Careful questioning of the Euro-Canadian sample and correspondence with their optometrists and ophthalmologists revealed no noticeable astigmatism in these subjects. Unfortunately, repeated attempts to gain similar information for the Cree sample from the local nursing station failed, although most of these subjects had had optometric testing within the last 2 years. As an added precaution, all subjects from both groups for whom corrective lenses had been prescribed were asked to wear their spectacles during the experiment. However, perhaps the strongest refutation of astigmatism as the cause of the differences reported here comes from the results themselves. That is, there was no significant effect of stimulus orientation for the Cree samples, and also no significant difference between the two groups with respect to the subject-orientation interaction. Finally, a check of data for individual Cree subjects did not reveal acuity patterns characteristic of astigmatism.

Alternatively, this difference in orientation anisotropy might be the result of genetically determined structural differences in the visual systems of the two groups. A within-culture comparison between Cree subjects raised in the traditional way and another Cree group raised in a carpentered visual environment would test this possibility. We have been unable to locate a sample fulfilling these requirements. While the possibility of genetically determined differences in the visual pathways of the two groups cannot yet be eliminated, we know of no evidence to support such an interpretation.

On the other hand, recent studies have shown that differential exposure to various stimulus configurations can produce long-lasting effects on visual physiology and behavior. We do not deny the importance of genetic determinants of visual feature extractors, but suggest that fine tuning may be affected by environmental demands. We suggest that the most parsimonious explanation of the orientation anisotropy in acuity is that it is the result of the preponderance of vertical and horizontal contours over other orientations in the early visual environment.

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11. This research was done while R.C.A. held a National Research Council of Canada bursary. Also supported by NRCC grant AO 353 to B.F.

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Reading and Sentence Completion by a Chimpanzee (Pan)

Abstract. *Four studies revealed that a 2½-year-old chimpanzee* (Pan), *after 6 months of computer-controlled language training, proficiently reads projected word-characters that constitute the beginnings of sentences and, in accordance with their meanings and serial order, either finishes the sentences for reward or rejects them.*

Recent reports indicate that language skills might not be limited to man. Gardner and Gardner (*1*) demonstrated that their chimpanzee, Washoe, mastered a sizable vocabulary of hand-produced words and that she chained them, occasionally, with apparent appropriateness to novel situations. Also, Premack (*2*) reported that his chimpanzee, Sarah, learned to use plastic objects as words and to attend to their serial arrangement in ways that suggested mastery of rudimentary syntax.

A computer-controlled training situation has been devised (*3*) to facilitate objective inquiry into the language capabilities of young apes. Four experiments conducted with a 2½-year-old female chimpanzee, Lana, in that training situation revealed that she can both read the beginnings of familiar sentences and appropriately complete them.

The language-training equipment (Fig. 1) accessible to Lana includes the consoles, each of which holds 25 word keys; a row of seven rearview projectors for visual display of communications; devices for dispensing various incentives that she requests (food, liquids, music, movies, toys, and so forth); and a device that opens a window for viewing the outdoors. This language-training equipment is interfaced with a PDP-8 computer that monitors Lana's performance, controls a teletype that records all that transpires, and dispenses appropriate incentives whenever her serial depression of the word keys conforms with the rules of the correlational grammar of the language, Yerkish. The computer is also capable of mediating conversation between man and ape, an eventuality for which we hope. Last, there is a second word key console, accessible only to us. This console, also monitored by the computer, was used in the experiments to initiate selected word chains, that is, sentences.

Each Yerkish word, or "lexigram," is a distinctive geometric white symbol on a colored background. The symbol is composed from nine stimulus elements, singly or in combination; the colored background is produced through the use of three colors, singly or in combination. All lexigrams can be produced by the last six projectors, each of which contains film for the stimulus elements and colors. The first projector can produce only a few terms that activate appropriate subroutines of the computer when certain sentences are started—*please* (for all requests), *?* for questions, *no*, and *yes* (*4*).

On the surface of each word key is a color-coded lexigram. Each key is constructed of laminated clear acrylic plastic. Lamps located behind the keys allow for (i) no backlighting, when the keys are inoperative; (ii) low-intensity backlighting, when the keys are opera-