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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10. Although the statistical comparisons in the text indicate a difference in the form of the orientation anisotropy between the two groups, matched *t*-tests between all possible combinations of stimulus orientation for the Cree sample indicate that the only significant difference ($P < .05$) was between vertical and left oblique acuity scores.
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.

20 February 1973; revised 8 June 1973

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.

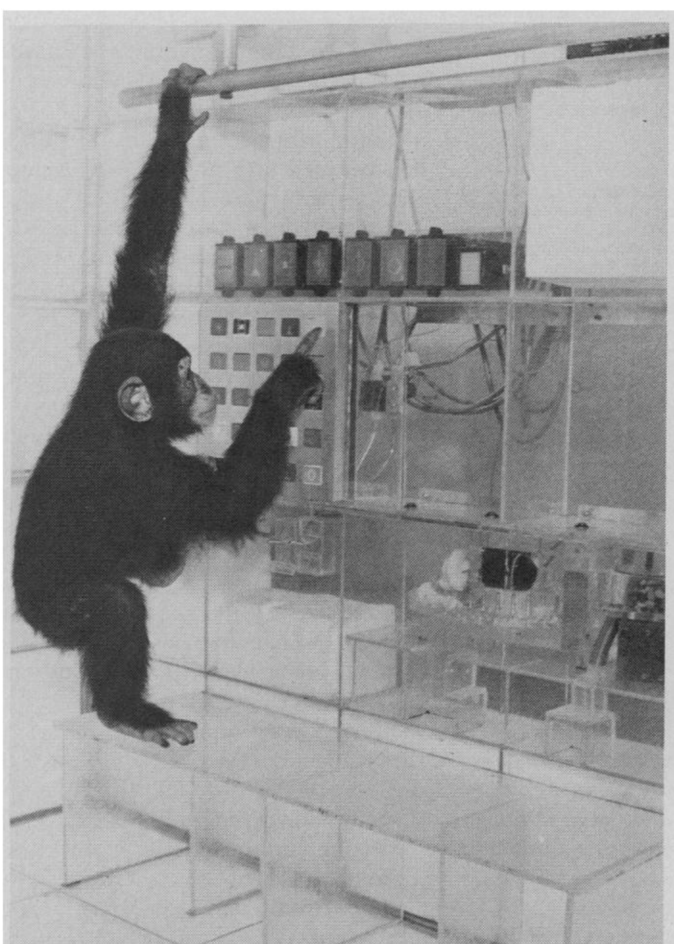
Each Yerkish word, or "lexigram," is a distinctive geometric white symbol on a colored background. The symbol is composed from nine stimulus elements, singly or in combination; the colored background is produced through the use of three colors, singly or in combination. All lexigrams can be produced 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 operative; and (iii) high-intensity backlighting, which signals Lana that she has successfully depressed the key, whereupon a facsimile of the lexigram on the key surface appears on a projector above the console (*5*). The consoles were designed to allow for alterations in the positions of keys so that the location of a key would not reliably indicate its meaning.

Each sentence must be ended with depression of the period key, which signals the computer to evaluate the communication. If the communication is unacceptable (incorrect), the computer just erases the projected images and resets the word keys; but if the communication is acceptable, the computer also activates the dispensing or control unit appropriate for the requested incentive or event (music, movie, and so forth) and sounds a tone.

Lana's initial training consisted of (i) pressing single keys to request various incentives; (ii) then preceding each request with *please* and following it with *period*; (iii) then pressing any key of a holophrase (composed of symbols on separate keys in the correct order)—for instance, *machine give M & M* (*6*)—preceded by *please* and followed by *period*; (iv) then pressing any key for each part of a fractionated holophrase—such as *machine give/ M & M*—preceded by *please* and followed by *period*; (v) then pressing each key of a correctly ordered series of words once treated as a holophrase, with *please* and *period*—for instance, *please / machine / give / M & M / period*; (vi) then pressing the keys in the correct order with the linear sequence of the keys randomized; and (vii) finally selecting and depressing the keys in the correct sequence, with the keys randomly assigned among others on the console. Without any special training, Lana came to attend to the production of the lexigrams on the projectors, possibly because their illumination coincides with the depression of keys. Lana has discerned that there is no point in continuing a sentence once an error has been made; she erases it by pushing the *period* key and tries again. This self-acquired adaptation to errors suggested that if we were to initiate sentence beginnings she might attempt to complete only those that were valid (acceptable to the computer) in accordance with her experience, and erase other sentence beginnings that were invalid (unacceptable to the computer).

The experiments were conducted to determine whether Lana, after 6 months of language training, was capable of reading sentence beginnings (produced by us through use of our keyboard and projected word by word from left to right on Lana's projectors) and, thereby, capable of discriminating between those that were valid and those that were invalid. We believe



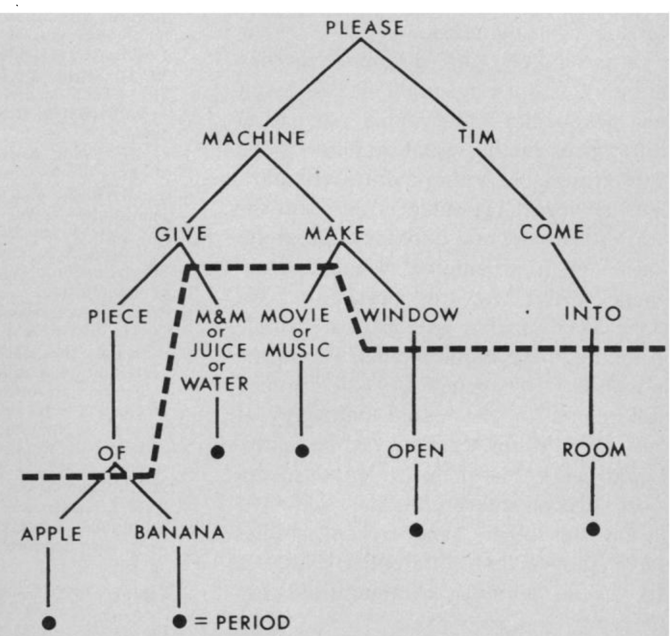


Fig. 1 (left). Lana's computer-controlled language training situation. The overhead bar must be pulled to activate the console. Facsimiles of the lexigrams on the surfaces of the word keys are portrayed on the projectors above the keyboard, from left to right, as the selected keys are pressed. Shown on the projectors is *please machine give piece of banana*; Lana is about to press the *period* key. Juice and water dispensers are immediately below the console; banana and M & M dispensers are shown at lower right. (Additional keyboards have been added to the right of the one shown, the only one operative when these studies were done.) Fig. 2 (right). Sentence beginnings and valid endings in experiments 3 and 4. Sentence beginnings are given above the dashed line; all of the keys for these words, except *please*, were operative and used by Lana in her attempts to complete the sentences. All of the options below the dashed line were available in experiment 4; *apple*, *juice*, *water*, and *music* were not operative in experiment 3. *Tickle* and *Lana* are not shown below the dashed line because they could not be used to complete the sentence beginnings tested.

that reading as a perceptual process was being assessed, because Lana had to attend to the serial order of lexigrams as well as to their meanings. Lana's reading was inferred from the accuracy with which she successfully completed sentences that were validly initiated and appropriately rejected, by prompt erasure, invalid sentence beginnings.

In the first experiment, we produced one valid sentence beginning along with six other invalid beginnings. The valid beginning was *please machine give*, to which Lana could add, at her option, *juice, M&M*, or the correctly ordered sequence *piece, of*, and *banana*. In addition to these correct options, there were others that were incorrect in view of her training and the computer's program—*machine, give, movie, make, Tim, Lana*, and *music*. *Machine* and *give* were clearly irrelevant as choices, for they were in the sentence's beginning. Because the system is programmed to respond to *machine make* (not *give*) *music* and *movie*, they were incorrect options. And, lastly, Lana had not been trained how *Tim, Lana*, and *make* might be added to a sentence that starts, *please machine give*; hence, they, too, were not viable options.

Invalid sentence beginnings were generated through random substitution of *juice, M&M, piece, of, banana, movie, make Tim, Lana*, and *music* for either *machine* or *give* or for both *machine* and *give*, and by incorrectly sequencing *machine* and *give*. Examples of invalid sentence beginnings, to which Lana's correct response would be to promptly depress the *period* key rather than to attempt sentence completion destined to fail, are *please piece give, please machine Tim, please movie Lana*, and *please give machine*. The valid sentence beginning occurred every fifth trial; the other four trials were a random series of invalid beginnings. There were 41 presentations of valid beginnings and 114 of invalid beginnings.

Lana was 100 percent correct in sentence completion on the valid trials, *please machine give*. On the invalid sentence beginning trials she was correct, by promptly depressing the *period* key, on 88 percent of the *please "X" give* trials (where *"X"* is any of the above-listed words), 95 percent of the *please machine "X"* trials, and 93 percent of the other possible invalid trials—*please "X" "X," please "X" machine, please give "X,"* and *please give machine*. Her relatively poor performance with *please "X" give* reflects many attempts at sentence completion in her first test session.

In the second experiment all conditions remained constant except that *make* was substituted for *give* in the valid sentence beginning. For successful completions, Lana had the options of *window, open, music*, and *movie*. To remove the window shade for 30 seconds of viewing the outdoors, Lana had to add *window open*; to see a movie or listen to music (for 30 seconds) she had to add *movie* or *music* to *please machine make*. With this sentence beginning, Lana could not succeed in asking for M&M's or juice, though these keys remained functional. (*Piece, of*, and *banana* were deleted from the keyboard and replaced by *window, open*, and *water*.)

That Lana had had much less experience with *make* than with *give* (2 weeks compared to 4 months) probably accounts for her relatively lower success (86 percent) in completing *please machine make*. On the invalid sentence-beginning trials, Lana was 88 percent correct on *please "X" make*, 100 percent correct on *please machine "X,"* and 99 percent correct on all other invalid trials—*please "X" "X," please "X" machine, please make "X,"* and *please make machine* (with correct performance still defined as prompt depression of the *period* key).

At best, the probability of Lana being correct by chance on any one trial of the first two experiments was less than 10 percent (12 active keys, excluding 13 inactive keys). That overall she was 95 percent correct renders chance an unlikely determinant of her performance.

In the third experiment, only valid beginnings were used: (i) *please*, (ii) *please machine*, (iii) *please machine give*, (iv) *please machine give piece*, (v) *please machine give piece of*, (vi) *please machine make*, (vii) *please machine make window*, (viii) *please Tim*, (ix) *please Tim come*, and (x) *please Tim come into* (Fig. 2). Successful sentence completion was required for correct performance; depression of the *period* key prematurely counted as an error. These sentence starts were randomly presented for 100 trials, 10 trials for each. When one word was presented, Lana was 80 percent correct; two words, 70 percent correct; three words, 76 percent correct; four words, 74 percent correct; and five words, 100 percent correct.

In the fourth experiment, procedures were identical to the third experiment except that the additional options of *apple* (to follow *piece of*), *juice, water, music, tickle*, and *Lana* were added. Her accuracy scores with sentence starts from one to five words were 100, 65, 93, 100, and 95 percent, respectively.

The results of these four experiments are taken as evidence that Lana accurately perceives Yerkish words, reads their serial order, and discriminates whether they can or cannot be completed in order to obtain the various incentives. And if successful completion of the valid sentence starts is viewed as analogous to typewriting, it can be said that Lana both reads and writes. Alas, we have no evidence of her ability for the third "R," arithmetic.

Our ultimate goal is to better understand the etiology of language development in man; our immediate goal is to determine unequivocally the anthropoid's capacity for linguistic production, including conversation.

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4. Sentences that commence with other than these four terms, as in conversation, are produced through programming that bypasses activation of the first projector.
5. Lana has learned on her own that unless the key pressed becomes brighter, there is no chance that continuation of her sentence will result in reward. Consequently, when a pressed key fails to become brighter, as when a relay occasionally fails to lock in, she presses the key again and again, if necessary, until full brightness is noted.
6. M&M's are chocolate candies (Mars, Inc., Hackettstown, New Jersey).
7. Research supported by NIH grants HD-06016 and RR-00165. We thank H. Warner, P. Pisani, J. V. Brown, and C. L. Bell for their professional assistance.

26 June 1973