1906, 39½ in 1938; Cornell 33, 25½; Dartmouth 6, 1; New York 9, 7; Clark 7, 1; Indiana 6, 3; Missouri 9, 1; and Wesleyan 7, 4.

Since the 1938 edition of "American Men of Science" was put into type, more than a dozen men starred in 1921–1937 have died and several have moved. Hence the data given above are only approximately correct. A recently issued federal report[2] gives the distribution of starred scientists who were not yet 66 early in 1938. According to that table, which counts equally all persons in any way connected with the institution (not giving half weight as was done in the above article), Harvard, in 1938, had 83 starred scientists under age 66, Chicago 54, Columbia 50, California 47, Yale 41, Hopkins 36, Princeton 34, Minnesota 29, Michigan 28, Stanford 28, Cornell 26, Pennsylvania 25, California Institute of Technology 25, Wisconsin 22, Massachusetts Institute of Technology 22, Illinois 21. In federal service: the Geological Survey had 20, Bureau of Standards 16, Smithsonian Institution 11, Department of Agriculture 10; all other bureaus a total of 14.

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[2] ''Research—a National Resource,'' (1) ''Relation of the Federal Government to Research,'' National Resources Committee, December, 1938.

SPECIAL ARTICLES

PRE-LINGUISTIC SIGN BEHAVIOR IN CHIMPANZEE

THE expression "symbolic behavior" has been used frequently for types of adaptation which resist explanation by accepted principles of "animal learning," or even as substitute for "insight" and "higher mental processes." It is true that some of the most impressive contrasts between the behavioral capacities of man and other primates may be attributed to linguistic process or neural mechanism which is present in the former and either absent or rudimentary in the latter. Thus the great difficulty of double alternation[1] and temporal maze[2] problems for animals other than man may be attributed to inability to count. Likewise, differences in ability to respond to complex, obscure or novel relations, as in multiple-choice problems,[3] in rate of acquiring simple discrimination habits and in various tests of "reasoning" and "insight," are subject to a similar anthropomorphic explanation.

Analysis reveals, however, that many of these manifestations of behavioral adaptivity can be accounted for, without the postulation of symbolic processes, in terms of innate and acquired perceptual organization, generalization, transfer, processes involved in delayed conditioning and other relatively simple and widely applicable determinants of animal behavior. For example, performance in double alternation and temporal maze experiments might be explained as differential conditioning to two stimuli in a series of intra-organic stimulus-responses initiated by the external situation. Logically viewed, adaptive response to relations of varying degrees of complexity and unusualness, as widely exhibited in the animal kingdom, should not require the appearance of an entirely new process at some point in the series of events. Indeed, few if any of the attempts to account for tool using or construction and for other presumptively "insightful" problem solutions, occasionally exhibited by animals, have excluded the possibility that perceptual organization and transfer may suffice as principles of explanation.

Considerations, elsewhere discussed,[4] which suggest the operation of symbolic processes in delayed response will be summarized briefly. In infrahuman animals the establishment of a discrimination habit *in the absence of spatial cues* commonly requires a large number of differential rewards and frustrations, whereas the establishment of a comparable habit in delayed response tests *when spatial cues are available* may occur in a single trial and with signified versus actual reenforcement.[5] This contrast may be accounted for by the relative obtrusiveness and prepotency of the two varieties of cue or by the diversity of mechanism operative in the two cases. Man adapts as promptly to the delayed response type of situation without spatial cues as with them. It seems probable that his success is due entirely to capacity for linguistic response —use of symbols for white-black or right-left, as the case may be. The diverse observations cited may be brought into relation by assuming (*a*) that delayed response requires the mediation of a symbolic process and (*b*) that some of the vertebrates are capable of symbolic response to spatial but not to non-spatial cues. The latter assumption is strongly supported by the relative frequency and evident significance of spatial factors in the lives of most animals.

For present purposes a symbolic process may be conceived of as a differential, and usually implicit,

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[1] W. S. Hunter, *Jour. Genet. Psychol.*, 35: 380*ff.*, 1928.

[2] S. D. S. Spragg, *Comp. Psychol. Monog.*, 13: 2, 38*ff.*, 1936.

[3] R. M. Yerkes, *Comp. Psychol. Monog.*, 10: 1, 89*ff.*, 1934.

[4] H. W. Nissen, A. H. Riesen and V. Nowlis, *Jour. Comp. Psychol.*, 26: 361–386, 1938. See also W. S. Hunter, *Behav. Monog.*, 2: 1, 1913, and *Psychol. Rev.*, 31: 478–497, 1924.

[5] J. T. Cowles and H. W. Nissen, *Jour. Comp. Psychol.*, 24: 345–358, 1937.

response established by previous training, whose "meaning," as exemplified by its positive or negative valence, is extremely labile. The sign response is differential in the sense and to the extent that it varies for different stimuli. It is especially significant that unambiguous differential delayed conditioning has been reported only for cases in which the stimuli were spatially differentiated. In discriminational behavior, including delayed response, lability of the consequences of sign response is manifest by the readiness with which approach and avoidance may replace one another. This feature of symbolic behavior distinguishes it from all instances of habit acquisition, including delayed conditioning, in which the nature or direction of the overt response is fixed only after many trials and can be changed or reversed with difficulty. This characterization of symbolic process differs to some extent from all the many definitions proposed. It is less limited than most of them, more specific than some. In common with other conceptions of symbol, it exhibits relationships to language, the outstanding difference in this respect appearing in what Morris[6] designates as the "pragmatical dimension of semiosis." We are interested in the experimental and systematic consequences of the concept of symbolic process, not in the problem of terminology.

Inasmuch as it has been demonstrated[7] that delayed response in the absence of spatial cues is possible for young chimpanzees, but only after very extensive training, it seemed to us not improbable that mature individuals, with the advantage of more varied experience, might possess this ability in higher degree and consequently be capable of prompt adaptation. To test this possibility, a survey was made of the reactive capacities of members of the Yale chimpanzee colony.

Twenty-four individuals (19 adult, 5 adolescent; 4 male, 20 female) were tested in the summer of 1938 by the following procedure. After brief preliminary training of a subject, two rectangular wooden boxes, with hinged lids, the one painted white, the other black, were displayed before the animal and it was permitted to see a piece of apple placed in the box at its right. Thereupon the boxes were taken up by the experimenter and shifted in position relative to one another beyond the range of the subject's vision. They were then presented before the netting wall of the animal's cage in such manner that it could definitely indicate its choice by lifting the lid of one box. The food-containing or correct box might be at the right, left, above or below a central point, and the white and black boxes were used with equal daily frequency and in irregular, predetermined order.

At the outset the experimenter shifted the boxes by turning his back upon the subject. At first 2, and later 4, trials were given per day. Under these simple conditions most of the subjects were given 96 trials.[8] The interval during which a box was hidden from a subject was not more than 2 or 3 seconds.

During this phase of the investigation, individual differences in the pattern of response and degree of success were extreme. Thus some individuals tried to follow the boxes visually as they were being shifted; others did not. Some acted as if keenly interested, eager and expectant of success; others as if relatively indifferent or lacking confidence in their ability to secure the food. The percentages of correct response for individuals ranged from 44 to 99. The average for all individuals in a total of 2,183 trials is 65 per cent. The subject who succeeded best made only one mistake in 96 trials, although she apparently made no effort to follow the boxes visually or to maintain direction of attention or bodily orientation during the brief interval of delay.

On the basis of the above results, the 8 individuals with highest scores (99, 94, 90, 86, 81, 72, 72, 69 per cent. correct) were selected for further use. Each subject was given a series of 10 trials daily, with predetermined order of use of the white and black boxes and of the presentational position and relation of the boxes. Shift of the boxes was effected behind an opaque screen, and they were invisible to the subject during this process for not more than 5 to 8 seconds.

In their first hundred trials these 8 animals ranged from 44 to 58 per cent. correct choices. Success in daily series varied from 20 to 90 per cent. Six subjects were above 50 per cent. correct, the chance score.

Once more the most successful subjects were selected and the experiment continued with 5 individuals. There was no immediate change in procedure. Success varied between 57 and 64 per cent. in the second hundred trials. For the third hundred, effort was made to attract the attention of the subject to the correct box by holding it up to view after it had been baited and by pointing to it as the subject watched box and experimenter.

At the end of the third hundred trials the experiment was discontinued because of evidence of diminishing success and varied behavioral indications of increasing discouragement and frustration. Witness the percentages for the last hundred trials, which range from 43 to 63, and also the results for the total series of 300 trials when percentages are figured by successive groups of 50 trials: 47.8, 55.8, 59.6, 61.6, 51.6, 58.4.

The accompanying condensed table presents data for the 5 subjects (2 males and 3 females, aged 8 to 14 years) who were used in the preliminary stages of the investigation and throughout the 300 trials reported in the table.

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[6] C. W. Morris, "Foundations of the Theory of Signs," Univ. Chicago Press, pp. 29*ff*., 1938.

[7] H. W. Nissen, A. H. Riesen and V. Nowlis, *op. cit.*

[8] In 9 cases the trials varied between 45 and 95.

TABLE 1

Subjects	Average per cent. correct				Range in per cent.
	1–100 trials	101–200 trials	201–300 trials	Total	
Alpha	54.0	59.0	63.0	58.7	30–90
Bimba	54.0	57.0	61.0	57.3	30–80
Bokar	54.0	64.0	56.0	58.0	40–80
Frank	58.0	60.0	43.0	53.7	20–90
Lia	53.0	63.0	52.0	56.0	20–90
Total correct ..	54.6	60.6	55.0	56.7	
Total W correct.	52.0	57.2	54.0	54.4	
Total B correct.	57.2	64.0	56.0	59.1	

Behavior in these tests indicated adequacy of motivation, and as a rule diligence of effort to choose the correct box in order to obtain the food. There were many daily series in which success exceeded chance by 20 to 40 per cent., but in no case was perfection of response achieved, even for a single daily series. The degree of success exhibited, together with the behavior of the subjects in making their choices, convince us that some cue or cues, unobservable directly by us, were operative. Among them may have appeared symbolic process representative of white box or black box. But, if this occurred, it is clear that it did not function readily and smoothly, for the subjects obviously worked very hard to adapt to a situation which for the normal human being is extremely easy, and, moreover, they often were much disturbed emotionally. It appears that, whereas the "thereness" of the correct box may readily be responded to by the chimpanzee, the "thatness"—as exemplified by a symbolic process equivalent to rectangular whiteness—is used with difficulty and uncertainty. Nevertheless, it is our opinion, based upon the results of varied and long-continued training experiments, that symbolic processes occasionally occur in the chimpanzee; that they are relatively rudimentary and ineffective; and that our experiments with subjects ranging in stage of development from early childhood to maturity have supplied no convincing evidence of the increase in frequency and functional value of symbolic response with increase in experience and age.

In our findings we consider most significant the evidence that delayed response, in the absence of spatial cues or with misleading cues, is either extremely difficult or impossible for most chimpanzees. This suggests that we may have happened upon an early phylogenetic stage in the evolution of symbolic process. There is abundant evidence that various other types of sign process than the symbolic[9] are of frequent occurrence and function effectively in the chimpanzee.

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[9] C. W. Morris, *op. cit.*, pp. 17*ff.*, and E. A. Esper, chapter 11 in "A Handbook of Social Psychology," Clark University Press, pp. 426*ff.*, 1935.

SYNTHESIS OF ASCORBIC ACID IN EXCISED ROOTS OF THE WHITE MOONFLOWER

ASCORBIC acid is of very wide-spread occurrence in the roots of plants. The site of its synthesis constitutes a problem of considerable interest. Studies with intact plants are complicated by the possibility of transport from other organs. The answer to the question as to whether or not ascorbic acid is synthesized by the roots themselves can best be obtained by studies on excised roots.

Seeds of white moonflower (*Calonyction aculeatum*) were sterilized and germinated in darkness. When the radicles had attained a length of 2 to 4 cm the tips (1.5 cm long) were excised and transferred to flasks of nutrient solution. The composition of the nutrient solution was as follows: $Ca(NO_3)_2$ 0.0006 M; KNO_3 0.0008 M; $MgSO_4$ 0.00015 M; KCl 0.00087 M; $Fe_2(SO_4)_3$ 0.000006 M; $MnSO_4$ 0.000002 M; $Na_2B_4O_7$ 0.0000023 M; glucose 2 per cent. The cultures were kept at room temperature; one half of each set was exposed to diffuse daylight throughout the culture period, whereas the other was maintained continuously in darkness.[1]

Ascorbic acid determinations were made of samples of roots grown in the culture solution and of samples of seedling roots of the size and age of the original explants. The vitamin C content of the tissues was determined by a modification of the Tillmans method.[2] A combination of 8 per cent. metaphosphoric acid in 8 per cent. acetic acid was employed in extracting the juices.

Table I presents the results of three experiments involving 20 determinations on 132 cultures. Each value in the table represents an average of 2 to 4 tests. The data show that roots cultured in light contained approximately 4 to 10 times the quantity of ascorbic acid in the original explants, whereas those cultured in dark-

TABLE I

ASCORBIC ACID CONTENT OF EXCISED MOONFLOWER ROOTS

C content of roots similar in age and size to original explants		Cultures in dark		Cultures in light		Culture period
mg/g fresh wt.	mg/root	mg/g fresh wt.	mg/root	mg/g fresh wt.	mg/root	(wks.)
0.135	0.0039	0.0263	0.0042	0.0638	0.0158	14
		0.0322	0.0038	0.1100	0.0398	8
		0.0292	0.0039	0.0984	0.0293	8

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[1] Facilities for the culture work were very generously made available by the Botany Department of the George Washington University. A detailed account of the culture technic will be published separately in Smithsonian Institution Miscellaneous Publications.

[2] R. R. Musulin and C. G. King, *Jour. Biol. Chem.*, 116: 409-413, 1936.