Concept Formation in Chimpanzees

Abstract. Animals performed with a high degree of accuracy on two concept problems. The bases of these performances, however, differed qualitatively. In one problem, successful performance was based upon responding to specific stimulus patterns. In the other problem, successful performance was based upon responding to the common element or concept.

Learning to respond to a class of stimuli on the basis of some common physical characteristic is referred to as "concept formation." Although concept formation has been demonstrated in animals (*1*), the experimental analysis of this complex behavioral process has received little attention in recent years. This report presents some results obtained with a new technique for the study of concept formation (*2*).

The two subjects were food-deprived chimpanzees. These animals had been trained to press a telephone key for food reward (reinforcement). Above the telephone key there were nine small Plexiglas windows arrayed in a 3-by-3 square. Stimulus patterns were programmed by illuminating some Plexiglas windows while leaving others dark. A sequence of 26 successive stimulus patterns, 13 positive and 13 negative, could be programmed (*3*). The positive stimulus patterns were characterized by a common element which was not present in any of the negative patterns.

During the presentation of positive stimulus patterns, a 100-response variable-ratio schedule of reinforcement was in effect—that is, the number of times that the subject had to press the key for food varied randomly from 1 to 200, with a mean of 100 (*4*). Positive stimulus patterns terminated at reinforcement. During the presentation of negative stimulus patterns, extinction was in effect —that is, responses were not reinforced. Negative stimulus patterns terminated when the animal had not pressed the telephone key for 1 minute. Experimental sessions were interrupted for a 30-second "time-out" period after the termination of each stimulus pattern and ended when 50 reinforcements had been delivered (*4*). The experimental procedures were automatically programmed, and the results were automatically recorded.

Two concept problems were investigated. Initially, on each of these problems, the animals were repeatedly exposed to one sequence of stimulus patterns. When the animals' behavior showed no consistent trend, the stimulus patterns were presented in a new sequence, but none of the specific stimulus patterns was changed. After several experimental sessions on the new sequence, 6 positive and 6 negative stimulus patterns were changed. However, the concept was not changed.

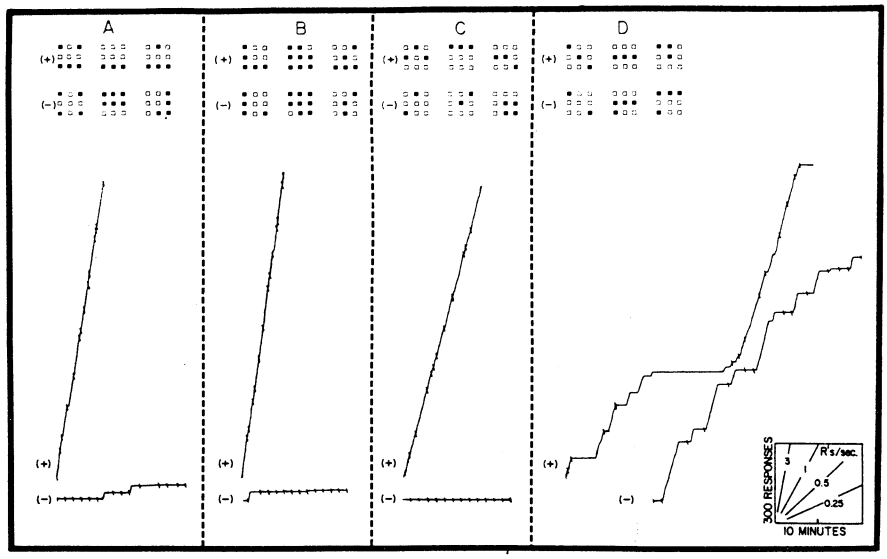

Fig. 1. Representative stimulus patterns and cumulative response curves, showing the effects of changing specific stimulus patterns without changing the concept. Sections *A* and *B* are from the first concept problem; sections *C* and *D* are from the second concept problem.

Representative positive and negative stimulus patterns from each of four sequences are shown in the upper sections of Fig. 1. The dark squares correspond to illuminated windows. Cumulative response records from each of the four sequences are shown in the lower sections of Fig. 1. Responses during positive and negative stimulus patterns were recorded separately, and they are presented in the upper and lower curves, respectively. The short diagonal strokes on these curves indicate the points at which stimulus presentations terminated. The records did not run during the 30-second intervals between stimulus presentations. Coordinates and representative slopes are presented in the lower right corner of the figure.

The stimulus patterns in the upper section of Fig. 1*A* exemplify the first concept problem. The illumination of the bottom row of windows was the concept. The cumulative response records in the lower section of Fig. 1*A* show the performance that had developed after about 100 experimental hours on the first sequence of stimulus patterns. The animals responded at high rates during positive stimulus patterns, but they seldom responded during the negative stimulus patterns. When the stimulus patterns were presented in a new sequence, there was no disruption of this performance. When 6 positive and 6 negative stimulus patterns were changed without changing the concept, there was still no disruption of the performance. For example, the stimulus patterns shown in Fig. 1*A* were changed to those shown in Fig. 1*B*. Cumulative records from the first sequence following the change are shown in the lower section of Fig. 1*B*.

The stimulus patterns in the upper section of Fig. 1*C* exemplify the second concept problem. The illumination of three windows was the common element in positive stimulus patterns; two or four windows were illuminated in negative stimulus patterns. The cumulative response records in the lower section of Fig. 1*C* show the performance that had developed after about 150 experimental hours on this sequence. As in the first concept problem, this performance was not disrupted when the stimulus patterns were presented in a new sequence. However, when 6 positive and 6 negative stimulus patterns were changed without changing the concept, performance was markedly disrupted. The changed stimulus patterns are exemplified in the upper section of Fig. 1*D*; cumulative response records from the first sequence following this change are shown in the lower section of Fig. 1*D*. There was excessive initial pausing in two of the positive patterns, and high rates of responding prevailed in the negative patterns that had been changed.

The animals developed clear discriminations on both concept problems. Neither discrimination was affected by changing the sequence in which the stimulus patterns were presented. However, the discriminations were differentially affected by changing specific stimulus patterns without changing the concept. Thus, the discriminations were qualitatively different. In the first concept problem, the discrimination was based upon response to the common element. In the second concept problem, the discrimination was based upon response to specific stimulus patterns—that is, the chimpanzees were respond-

ing appropriately to at least 12 specific stimulus patterns presented in successive fashion. In further studies, it would be possible to determine the maximum number of specific patterns to which these animals could respond effectively. Until such studies have been completed, investigations of complex discriminations with chimpanzees should be interpreted with caution, until the bases of the discriminations have been assessed.

With the procedure described above, concept formation was a function of the concept problem. The common element of the first concept problem (the bottom row of windows) had a specific spatial location; the common element of the second concept problem (any three windows) did not. This difference in the level of abstractness of the two problems may have been an important factor. With a different procedure, the chimpanzees could probably have been trained to respond to the common element of the second concept problem. If the stimulus patterns were changed after each sequence without changing the concept, for example, the animals would have been unable to maintain a discrimination by responding to specific patterns.

ROGER T. KELLEHER*
Yerkes Laboratories of Primate Biology, Orange Park, Florida

References and Notes

1. P. E. Fields, *Comp. Psychol. Monograph No. 9* (1932); B. Weinstein, *Genet. Psychol. Monograph No. 31* (1945), p. → L. H. Hicks, *J. Comp. and Physiol. Psychol.* 49, 212 (1956).
2. This investigation was supported in part by research grant M-1005 from the Institute of Mental Health of the National Institutes of Health, U.S. Public Health Service, and in part by the National Science Foundation. The technique presented in this report is similar to one used for studying concept formation in human bei → [E. J. Green, *J. Exptl. Psychol.* 49, 175 (1955)].
3. One negative stimulus pattern in which all windows were dark appeared in all sequences.
4. C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (Appleton-Century-Crofts, New York, 1957).

* Present address: Smith, Kline and French Laboratories, Philadelphia, Pa.

11 June 1958

Interpretation of Properdin Levels Determined by Phage Neutralization Technique

It has been demonstrated by Van Vunakis, Barlow, and Levine (*1, 2*) that the properdin system neutralizes the *Escherichia coli* phage T2r+ (*3*). These authors have described a precise and reproducible procedure for determining the phage neutralizing (PhN) activity of human serum and have suggested that it affords a means of measuring properdin levels (*4*). In brief, the technique measures phage neutralizing activity in terms of the amount of serum (PhN_{50}) required to neutralize 50 percent of the phage introduced into the system under the experimental conditions used. During the course of an investigation of the influence of complement (C′) on the neutralization of bacteriophage by immune antibody, some observations have been made that indicate the necessity for caution in interpreting properdin titers determined by the phage procedure. In addition, these findings suggest that concepts concerning the nature of the properdin system should be carefully reconsidered.

Table 1. Neutralization titers of human sera tested with T2, T6, and T7 bacteriophage. Diluent: 0.126*M* Veronal buffer, *p*H 7.4 to 7.6, containing 0.1 percent 5X crystalline bovine serum albumin (Armour & Co.), Ca^{++} (0.00015*M*), and Mg^{++} (0.0005*M*). Procedure: Reaction mixture tubes, sitting in an ice bath, were prepared, diluent (to give a final volume of 1.5 ml), serum dilutions, and phage (0.5 ml containing 7.5×10^4 infectious units) being added in that order. The tubes were well mixed and incubated for 90 minutes at 37°C. They were then chilled, diluted, and titrated for residual phage. PhN_{50} titers were calculated as described by Barlow *et al.* (*4*).

Serum	PhN_{50}/ml and indicator phages*			Hemolytic titer ($C'H_{50}$/ml)
	T2	T6	T7	
NH	20	24	19	24
B	15	20	28	Not done
KC	12(12)	28(24)	42(40)	31
G	25(22)	19(16)	7(8)	31
DM	24(24)	24(21)	56(43)	30
SB	16(14)	27(27)	4(3)	32
AC	9(8)	26(25)	13(10)	28
DB	15	31	35	41

* Figures in parenthesis are serum titers determined 3 to 4 months after the initial assay. Sera were stored at −35°C.

Several different phages of the T series (T2, T6, and T7) were to be used in this study, but the presence of normally occurring neutralizing substance (properdin) in the guinea pig serum being used as a C′ source presented an obvious complication. As was indicated by Barlow *et al.* (*2*), repeated absorptions of the serum with zymosan resulted in a C′ reagent essentially devoid of phage neutralizing activity. The present report stems from the observation that, prior to absorption with zymosan, this serum neutralized these three phages to varying degrees. It was wondered whether this variation could be attributed to a difference in susceptibility of the phages, or whether it perhaps indicated that this serum contained varying amounts of neutralizing substances directed against the different phage types. It was felt that these questions could possibly be answered by assaying several sera and by using all three phage types. If the differences observed were due to varying susceptibility of the phages to a single neutralizing substance, one would expect the ratio of serum titers obtained with the three different phages to remain approximately constant from one serum to another. On the other hand, the failure to obtain such a correlation would suggest that the neutralizing substance(s) had some degree of specificity and could be present in different sera in varying amounts.

Several human sera showing normal hemolytic C′ levels were assayed for activity against T2, T6, and T7 phages by a procedure similar to that described by Barlow, Van Vunakis, and Levine (*4, 5*). Heated serum samples were included in all cases, and no significant neutralization was found. As is shown in Table 1, no constant ratio occurs—that is, the phage neutralizing activity of a serum against one of the phage types does not necessarily correlate with its activity toward the other two. It is clear that if one were to use the neutralization of T6 or T7 as an indicator of serum properdin levels, one might obtain a distinctly different impression than he would if T2 were used. It is obvious that circumspect judgment is necessary in the evaluation of properdin levels determined by this procedure, and indeed, the question of the true nature of properdin is raised.

These findings not only raise the question of the significance of properdin levels determined by the phage technique but also indicate that properdin may have some degree of specificity which is suggestive of antibody. Nelson (*6*) has presented evidence and a hypothesis suggesting that the properdin system may be explained in terms of normally occurring antibody operating in conjunction with C′ without introducing the concept of the new entity, properdin. Skarnes and Watson (*7*) have indicated that properdin and normal antibody may be the same substance in view of the numerous properties shared by them.

From the data given in the present report, and also from the failure of others to find a satisfactory correlation between properdin titers determined by the zymosan assay method (*8*) with those determined by the phage tech-