the lipid had only a weak procoagulant effect, and clotting was observed in 60 seconds. This small effect accounts for the survival of animals when this lipid is given alone. It is only a weak procoagulant and has been called a partial thromboplastin. Clotting occurred in 6 to 7 seconds when 300 units of autoprothrombin C were in the mixture with the lipid (Fig. 1). The 300 units of autoprothrombin C alone produced clotting in 50 seconds in another test. In animals or test tubes either procoagulant is weak by itself, but when the two are combined the mixture is a strong procoagulant. The test-tube experiments correlate so well with work on animals that the results from one can practically be used to predict results in the other (*8*).

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26 February 1962

Transfer Effects of Successive Discrimination-Reversal Training in Chimpanzees

Abstract. Chimpanzees receiving successive discrimination-reversal training on a single pair of stimuli transferred almost perfectly to two additional reversal tasks and to a "learning-set" series of 180 discrimination problems. A "win-stay, lose-shift" strategy, however it is acquired, seems to be a sufficient basis for one-trial discrimination learning.

Training on multiple discrimination problems results in progressive improvement in performance culminating in one-trial learning of single problems. This effect has been described as the formation of a learning set, and it has been studied most intensively in the primates. Although learning set has been demonstrated in nonprimate forms, the rate of learning and asymptotic levels of performance are generally inferior to those achieved by primates (*1*). The sources of these phylogenetic differences have not been established; one possibility is that the primates are more capable of developing "hypotheses" or "strategies" which facilitate problem solution. Most of the theoretical and experimental work on learning-set formation, however, has focused on changes in the relative strength of responses to the physical properties and spatial relations of the stimulus objects as a function of training (*2*).

Restle, however, has suggested that the cues common to the correct stimulus objects in a series of discrimination problems, regardless of the physical attributes of the stimuli, are the properties of having been rewarded on the previous trial. According to this interpretation animals achieving consistent one-trial discrimination learning "use an abstract understanding of an LS [learning set] experiment, transcending the 'stimulus-response' rubric familiar in most theories of learning" (*3*). The behavioral contingencies through which this abstract principle is expressed may be described as a "win-stay, lose-shift" strategy. Levine (*4*) has shown that various strategies operate during learning-set formation. Furthermore, he has suggested that the gradual strengthening of a win-stay, lose-shift strategy by means of 100 percent reinforcement is largely responsible for learning-set formation.

If such a strategy is responsible for one-trial discrimination learning it should be possible to establish the strategy under one set of circumstances and transfer it to another. Accordingly, the present experiment was designed to determine whether chimpanzees given successive discrimination-reversal training on a single pair of stimuli would develop this strategy and show immediate transfer to a series of simultaneous discrimination problems with multiple pairs of stimulus objects (like those used in conventional learning-set experiments). It was further hypothesized that a second group trained on object-alternation would develop a "win-shift, lose-stay" strategy which would retard the formation of a learning set for conventional discrimination problems.

Chimpanzees were trained to displace a single stimulus object covering a food well before testing was begun. Testing was conducted with a standard discrimination testing apparatus (*5*). The subject's task was to displace one of two stimuli (differing from each other in several dimensions) in order to obtain a food reward. The interval between stimulus presentations was 5 seconds. If the animal's initial choice was incorrect, it was allowed to displace the correct object after a 5-second delay.

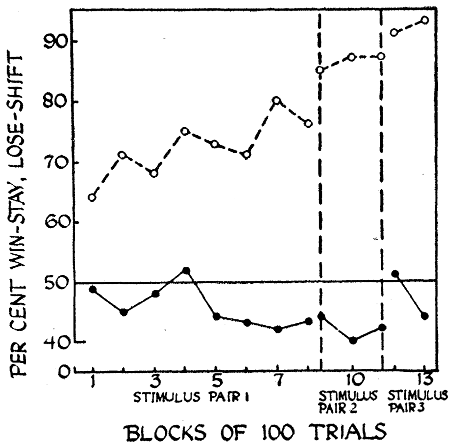

Fig. 1. Percentage of "win-stay, lose-shift" responses under two training conditions. Solid circles indicate progress of the discrimination-reversal group; open circles indicate lack of improvement for object-alternation group. Separation of data points indicates training on three different stimulus pairs.

The investigation consisted of two experiments. In the first experiment, seven experimentally naive adult chimpanzees were randomly assigned to two groups. One group ($N = 4$) received successive discrimination-reversal training on three stimulus pairs and the other group ($N = 3$) received alternation training on the same three stimulus pairs. The number of trials per stimulus pair for both training conditions is

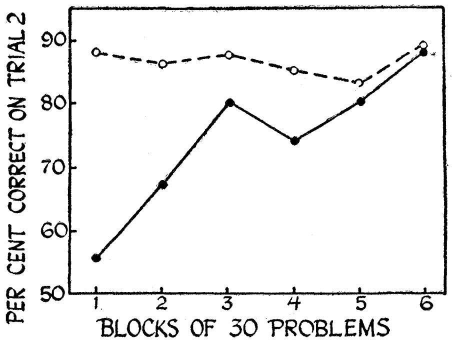

Fig. 2. Trial 2 performance on a learning set series of 180 discrimination problems after successive discrimination-reversal training (solid circles) and object-alternation training (open circles) on three stimulus pairs.

shown in Fig. 1. Prior to their training on each stimulus pair all animals were given a single discrimination-reversal test. The stimulus pairs used for the three discrimination-reversal tests were also used for the training phases. The criterion for discrimination-reversal learning was 12 consecutive correct responses.

The results of the training phases are shown in Fig. 1, which plots the mean percentage of win-stay, lose-shift responses for both groups as a function of 100-trial blocks. These curves reflect the number of correct responses. Improvement is indicated by a rising curve for the discrimination-reversal group and a falling curve for the alternation group. The discrimination-reversal group did show progressive improvement with extremely efficient transfer from one training phase to another, whereas the alternation group showed no such improvement. The latter group failed to solve the object-alternation task. The differential effects of training were further demonstrated by performance on the test series. Mean numbers of errors to criterion for tests 1, 2, and 3 were 57.8, 6.5, and 3.5 for the discrimination-reversal group, and 44.3, 38.7, and 45.0 for the alternation group. Matched t tests between tests 1 and 2 and tests 2 and 3 revealed significant positive transfer effects for the discrimination-reversal group (p's $< .05$) and no transfer for the alternation group. The differences between the groups on tests 2 and 3 were also significant (p's $< .02$). These results show clearly that chimpanzees positively transfer the effects of successive discrimination-reversal training on a single stimulus pair to a new stimulus pair.

The second experiment was undertaken to test the transfer effects of successive discrimination-reversal training to a learning-set series of 180 discrimination problems. Upon completion of experiment 1 all subjects received a series of ten, 6-trial discrimination problems each day for 18 days. Figure 2 presents the percentage of correct responses on trial 2 for each group as a function of problem blocks. Throughout testing the discrimination-reversal group appeared to obtain all the information necessary for problem solutions on the first trial. The effect was immediate and persistent. The alternation group showed progressive improvement, attaining consistent one-trial learning only after 90 problems. In spite of extensive alternation training the learning-set function produced by this group was similar to those functions obtained by Hayes *et al.* (*5*) on naive chimpanzees. On the basis of the results obtained in these two experiments we may conclude that a win-shift, lose-stay strategy was not established in the alternation group.

A study by Riopelle (*6*) indicated that relatively naive rhesus monkeys who were trained on a series of 216 discrimination problems, constructed from all possible combinations of four stimulus objects, showed a consistently high efficiency of learning when shifted to an ordinary learning-set series. In view of my results and those of Riopelle, it is suggested that the learning-set phenomena may arise from any training technique producing a win-stay, lose-shift strategy which transcends the physical properties of the stimulus objects (*7*).

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2 April 1962

Inhibition and Facilitation of Afferent Information by the Caudate Nucleus

Abstract. Stimulation of the caudate nucleus modifies inputs to the visual system of the cat. The modification of such sensory information is similar to the modification seen on stimulation of the thalamus and brain stem reticular formation. Preliminary stimulation of the caudate nucleus at different intervals prior to the afferent input may have facilitatory or inhibitory effects on both evoked potentials and unitary responses of the visual cortex.

Recently a considerable number of experimental data have shown that there is a striking functional similarity between the caudate nucleus and the reticular formation of the brain stem. In the case of both the caudate nucleus and the reticular formation, stimulation has yielded modification of monosynaptic spinal reflexes (*1*), low-frequency stimulation has produced a sleeplike syndrome (*2*), and high-frequency or strong stimulation has produced arousal (*3*). Further, stimulation of the caudate nucleus produces widespread bilateral evoked potentials and recruiting responses in the specific systems (*4*). It has been shown in microelectrode studies (*5*) that a convergent organization similar to the brain stem exists within the caudate nucleus, with cells responding to a variety of sensory stimuli—olfactory, auditory, somatosensory vestibular, or visual. The recent work of Albe-Fessard (*6*) and her collaborators has clearly demonstrated the polysensory character of neurons within the caudate and, in both macro- and microelectrode studies, has shown evoked and single unit responses in the caudate to multimodal stimulation. Electrophysiologically, the existence of long multineuronal chains in the caudate similar to those described for the brain stem reticular formation has suggested sustained reverberatory activity (*7*).

There remain, however, demonstrated functions of the reticular formation which have not yet been established as functions of the caudate nucleus. Stimulation of the reticular formation or of the diffusely projecting thalamic nuclei has facilitatory or inhibitory effects upon cortical responses to afferent stimuli (*8*). In the series of investigations reported here an attempt was made to determine whether such modification of sensory afferents could be achieved by stimulation of the caudate nucleus.

Operations were performed on 20 cats under ether anesthesia; these were followed by curarization and respiration. The exposed tissue margins were treated with procaine and the eyes were treated with atropine at regular intervals, and the experiments were begun after 3 to 5 hours, when the effects of the anesthesia had dissipated. Two types of afferent stimuli were used—a physiological stimulus (presentation in the dark of brief flashes of light from a photostimulator) and a nonphysiological stimulus [brief pulses (0.1 msec, 6 v) delivered to the nucleus center median of the thalamus]. Potentials were always recorded in the visual cortex, from either bipolar insulated stainless-steel electrodes or tungsten microelectrodes; the gross and the single-unit responses were recorded from the same electrode, the slow and the fast components being fed through two separate amplifiers with appropriate frequency settings. The thalamocortical stimulation or the light flash was preceded by a single brief pulse, or train of brief pulses, to the