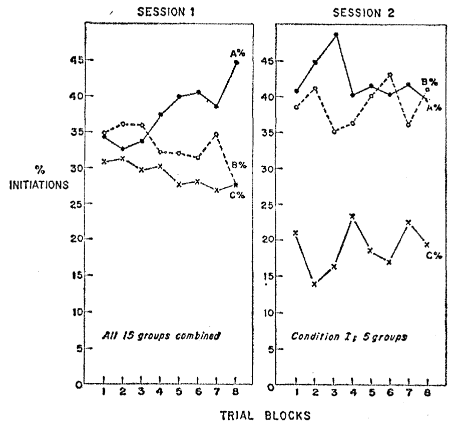

Fig. 2. Plot of average percentage of initiations made by A, B, and C subjects.

With the demonstration that speech sequences, disregarding their content, can be manipulated by differential reward, the question arose as to the implications of this social learning for decision making. Is the verbal learning an isolated phenomenon? What are the consequences for the roles persons take in achieving group decisions?

The concomitant effects on individual behavior are shown in Fig. 2, for all groups in the first session and condition I in session 2. The data consist of counted instances of color nominations made by each subject as an index of individual initiation in achieving decisions, for example, "Let's choose red." Initiation rate is plotted as a percentage of the initiations of the three subjects, accounted for by each subject.

The A subjects showed a considerable increase in their rate of initiation in session 1. In session 2, both A and B subjects were high, with A leading somewhat more often than B. Subject C tended to assume a less significant role in the decision making. The initiation data for conditions II and III in session 2 suggest that the role tendencies established in session 1 are altered by the change in the speech sequences necessary for positive reinforcement. However, no clear substitute pattern emerges within these conditions during the second session.

These data suggest that the process of learning speech sequences is not unrelated to changes in the instrumental behaviors of individual subjects in a group in attempting to achieve decisions and to find solutions to the experimental problem. Examination of contingency tables relating speech sequence and initiator over all trials support this contention. Thus, in reinforcing a given speech sequence, the roles taken by subjects in initiating group decisions were also reinforced. It would also appear (Figs. 1 and 2) that the effects of the reinforcement schedule on roles were more striking than on speech sequences themselves (*6*).

The results of this experiment suggest that the verbal behaviors of different individuals in a group discussion can become chained together in sequence under the partial influence of rewarding events in their common environment. This learning seems to take place without awareness. It seems probable that similar circumstances occur in natural groups where specific patterns of verbal interaction become established, perhaps through an adventitious coupling of a sequence of acts and some reinforcing event. That this phenomenon may have consequences for properties of group interaction other than the verbal interaction itself, for example, roles, has been demonstrated here. In addition to individual motives and propensities, we need to know more about the learning of social responses and effects of such learning on individual behavior in groups. The techniques for registering speech sequences described in this paper provide one means for further objective study of group behavior and interaction.

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Time Factors in Interhemispheric Transfer of Learning

Abstract. *Single-trial interhemispheric transfer of a discrimination task engram was studied by eliciting spreading depression unilaterally during acquisition of the discrimination. Complete transfer to the untrained side occurred after one trial with both hemispheres functional, if 10 minutes elapsed between this trial and the elicitation of spreading depression in the trained side. If depression was elicited 15 seconds after the trial no transfer occurred.*

Potassium chloride, when applied topically to one hemisphere of the brain, causes a decrease in electrical activity of that cortex (*1*). Previous investigators (*2*) have shown that under these conditions simple learning (such as bar pressing or shock avoidance) is localized in the opposite, functional, hemisphere. They have also reported that this learning is transferred to the other hemisphere after one trial with both hemispheres functional. In the experiments reported here, we used a discrimination task and studied the time necessary for the transfer to take place.

Water-deprived, male, albino, Holtzmann strain rats were used. Prior to the experiment longitudinal slots 5.0 mm long and 1.5 mm wide were placed on each side of the skull over the temporal-parietal area of the brain, 2.0 mm off the midline. Cotton pledgets saturated with saline were placed in the wound and changed daily to prevent healing. Each day during the original learning period the cotton pledget on one side was removed and replaced 10 minutes before the start of the trials with a pledget saturated with a 25-percent solution of KCl. This causes the development of a spreading depression of electrical activity in 3 to 4 minutes and maintains it for 3 to 4 hours (*3*). Each day after the trials the KCl-satu-

Table 1. Proportion of correct responses during each session after each rat had met the required criterion of learning. Symbols in parentheses indicate the hemisphere depressed.*

Subjects	Criterion day (XO)	Test days 1 (OX)	2 (XO)	3A (OO)	3B (OX)	4 (OX)	5 (XO)
				Group I			
Rat 1	5/6	0/1	2/2	0/1	0/4	0/2	4/4
Rat 2	5/6	0/1	2/2	1/1	0/4	0/2	4/4
Rat 3	5/6	1/1	2/2	1/1	1/4	0/2	Not run
				Group II			
Rat 4	5/6	0/1	2/2	1/1	4/4	2/2	4/4
Rat 5	6/6	0/1	2/2	1/1	4/4	2/2	4/4
Rat 6	5/6	0/1	2/2	1/1	4/4	2/2	Not run

* X indicates 25-percent solution KCl applied to this hemisphere; O indicates no manipulation on this side hemisphere. The initial hemisphere depressed (right or left) is not important. Only the relationships (which were randomly distributed), not the actual hemispheres are shown.

rated pledget was removed and replaced with one saturated with saline.

The animals were run daily in a simple T-maze. A light over the maze indicated that one arm would contain water; no light indicated that the other arm would contain water. Six trials were run in random order, three to each side of the maze, on each day until each rat reached "criterion day": when five correct trials were achieved in a given day with the last two trials correct.

When a rat had satisfied this criterion, no reinforcement was given during the days which followed (test days 1 to 5). On test day 1, the opposite hemisphere was depressed and performance was tested. On test day 2, the hemisphere depressed during original learning was again depressed and performance was tested. On test day 3 the animals were given one trial with neither hemisphere depressed (A trials) and then divided into two groups: group I had the KCl-saturated pledget applied 15 seconds after the completion of the single trial; group II had the KCl pledget applied 10 minutes after the trial. In both groups prior to these B trials the pledget was applied to the hemisphere which was functional, not depressed, during original learning.

Table 1 contains the results for six animals, three in each group. On test day 1 only one correct response was made when the hemisphere which was functional during original learning was depressed, indicating that learning had been restricted to the hemisphere active during acquisition. On test day 2, under conditions identical to those on criterion day, all animals performed the discrimination task perfectly. On test day 3, when both hemispheres were functioning (A trials) five of the six animals responded correctly. Fifteen seconds (group I) or 10 minutes (group II) after the A trials on test day 3, the KCl pledget was applied. In the B trials on test day 3 (30 minutes after the A trials) only group II showed a high level of performance. (With the Mann-Whitney test the difference between the groups was significant at the .05 level.) This was still apparent the next day (test day 4) when, again, the first group (pledget applied after 15 seconds) failed to show evidence of learning, but the second group performed perfectly. On test day 5, when the rats were again tested under conditions identical with those on criterion day (that is, the originally depressed side was again depressed), performance was perfect. Additional work with this paradigm has shown that successful one-trial transfer of learning with a 10-minute interval can be obtained in one trial in animals in which no transfer was demonstrated when a 15-second interval was used (*4*).

These data have major implications for neurophysiological theories of learning and memory. The failure to obtain interhemispheric transfer with a 15-second interval while obtaining it in the group subjected to a 10-minute interval is in line with present concepts of memory which posit an initial interval during which the material learned is primarily maintained through reverberatory neural activity and only gradually over time does a suprathreshold, permanent, structural change take place.

The work of Duncan (*5*) and others who used electroconvulsive shock would suggest that the interval after which disruption of this neural activity has no effect on retention is greater than the 10 minutes found in this study. A major difference between previous studies and this one, which possibly accounts for our finding of the shorter period of consolidation, is that in our procedure a well-established engram already exists in one hemisphere and needs only to be transferred to the other hemisphere. In the other studies the primary effect has been on the disruption of the acquisition of learning. Perhaps spreading depression elicited in both hemispheres after each learning trial would give consolidation periods closer to those obtained with electroconvulsive shock.

It is of interest that on test day 1, all the animals responded—that is, they moved from the start box to one of the goal boxes even though the functional hemisphere had never functioned previously during a trial. Response latencies for all animals were comparable to their average latency for the six trials on criterion day. This suggests that the animals had learned bilaterally to run the maze (possibly because this function is handled subcortically without essential cortical connections) and that cortical functioning is needed only for the discrimination task.

Another implication of this study comes from the fact that for the transfer trial (A trials) only one trial was given. The animal only had one stimulus—response experience with both hemispheres functional. On the test trials (B trials), however, in the 10-minute group, performance was perfect in both kinds of trials. This suggests that the single experience with only a part of the total task was adequate to transfer all the learning necessary for the entire discrimination task. One can refer to Hebb's (*6*) cell assemblies as a mechanism for this, but future studies will have to determine how much information can be grouped in a single interhemispheric transfer, and what percentage of this information must simultaneously occur in both hemispheres for the entire group to be transferred.

If the data obtained from all subjects on test day 1 is combined with the data for group I on test days 3 (B trials) and 4, there are 24 trials which can be viewed as trials in which the animals should respond as naive subjects. In these 24 trials only two "correct" responses were made. (The first day of acquisition when the other hemisphere was depressed and the functioning hemisphere was naive there were eight correct responses in group I and ten in group II.) This finding may be a highly improbable chance occurrence, or, as one possibility, the original learning may have been an inhibition of the incorrect response and the release of this inhibition, following depression of the trained hemisphere, made the incorrect response highly probable.

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Wavelength Generalization after Discrimination Learning with and without Errors

Abstract. *Pigeons were trained to discriminate between 580 mμ (S+) and 540 mμ (S−) by procedures which resulted in either a large amount of responding to S− or in little or no responding to S−. A shift in the peak of a postdiscrimination generalization gradient, away from S−, was obtained only if the discrimination was learned with a large amount of responding to S−.*

This report is concerned with two recently demonstrated phenomena that are related to the acquisition of a discrimination—the "peak-shift" in a postdiscrimination generalization gradient and "errorless" discrimination learning.

In his initial experiments on the peak shift, Hanson (*1*) trained pigeons to discriminate between two wavelengths, one correlated with reinforcement (S+) and one not correlated with reinforcement (S−). The discriminative stimuli were presented in successive alternation. Discrimination training continued until responses to S− had been extinguished below a predetermined criterion. The pigeons were then given a generalization test in which a series of 13 stimuli (including the original S+ and S−) were presented in a random sequence. The peaks of these gradients were displaced away from S+, in a direction which also moved them further away from S−.

I have shown that pigeons can be trained to discriminate between different wavelengths and between different orientations of a line without responding to S−, if discrimination training begins immediately after the response to S+ has been conditioned, and if the difference between S+ and S− is progressively reduced from an initially large value to the smaller final value (*2*). This finding raised the interesting question of whether a peak-shift would be obtained after the training of a wavelength discrimination without responses to S− (errors).

The experiment was performed in a standard conditioning apparatus (*3*) in which the response key, which was typically operated by the pigeon pecking at it, could be transilluminated by any one of 15 Bausch and Lomb monochromatic stimuli whose half-widths were each less than 12 mμ. All of the stimuli were equated with respect to apparent brightness by the addition of neutral density filters whose values were derived from Blough's photopic visibility function for the pigeon (*4*).

The subjects were nine White Carneau male pigeons, with no prior experimental history, who were equally divided into three experimental groups. The first group of birds (Nos. G-148, G-188, G-196) received 14 sessions of training in which the response key was transilluminated by a light of 580 mμ. Responses were reinforced on a 1-minute variable-interval schedule. At the end of each minute a shutter interrupted the beam of monochromatic light for 2 seconds to prepare the birds for the generalization tests during which the 2-second time-out period would be used for changing filters. Responses to the dark key were never reinforced.

Another group of pigeons (Nos. G-173, G-219, G-209) was trained to discriminate between 580 mμ (S+) and 540 mμ (S−) with virtually no responses to S−. The details of the training procedure, which are described elsewhere (*2*), may be summarized as follows. Responses to S+ were reinforced on a 1-minute variable-interval schedule of reinforcement; S− was introduced at the start of the second session. (The first session was used to condition the key peck to S+.) The duration of S+ was 1 minute and S+ was presented at a constant intensity throughout discrimination training. The duration and intensity of S−, however, were varied in three stages during the first discrimination session. During the first stage, the intensity of S− was held constant at a value that was 3.2 log units below the final intensity of S−, and the duration of S− was progressively increased from 2 seconds to 30 seconds over successive S− presentations. During the second stage, the duration of S− was held constant at 2 seconds and the intensity of S− was progressively increased from its initial value of −4.0 log units to its final value of −0.8 log units. During the final state, the duration of S− was progressively increased from 2 seconds to 1 minute. All three stages of varying S− occurred during the first discrimination session. Each bird received 14 sessions of discrimination training. The discriminative stimuli were always automatically changed during a 2-second time-out period that followed each S+ and each S− component; S+ and S− were successively alternated during the last five sessions. Birds G-173, G-219, and G-209 made 0, 1, and 4 responses to S−, respectively, during the 14 discrimination sessions.

The remaining three piegons (Nos. G-202, G-203, G-165) were trained to discriminate between (S+) and (S−) by a procedure similar to Hanson's. During the first seven sessions, only S+ appeared on the response key. At the end of each minute the key was darkened for 2 seconds. Responses to S+ during these sessions, and during the subsequent discrimination sessions, were reinforced on a 1-minute variable-interval schedule of reinforcement. Discrimination training started at the beginning of the eighth session. The stimuli S+ and S− were presented alternately in random succession and were each followed by a 2-second time-out period. Each presentation of S+ lasted 1 minute. The duration of S− was also 1 minute unless responses to S− occurred. Each response to S− delayed the termination of the current S− for 30 seconds. This procedure insured that responses to S− could not be secondarily reinforced by the subsequent appearance of S+. Birds G-202, G-203, and G-165 made 1636, 1560, 3060 responses to S−, respectively, during seven discrimination sessions. More than 90 percent of each bird's responses to S− occurred during the first two discrimination sessions. During the last three discrimination