and the crystallographic direction $c$, and $2V$ is the optic angle. For the orthorhombic form:

$$n_X = 1.772 \pm .003$$
$$n_Y = 1.780 \pm .002$$
$$n_Z = 1.789 \pm .002$$
$$(+)2V = 58° \pm 5°$$

A prominent prismatic cleavage yields fragments whose orientation prevents accurate determination of $2V$ in oil mounts. Monoclinic ferrosilite is clear or has a slight greenish tint; the orthorhombic form is faintly pleochroic in tints of green and yellow green.

Powder difractometer patterns of the two polymorphs (Table 2) are roughly similar to those of monoclinic and orthorhombic enstatite; the lines are all shifted to larger $d$ values. A strong preferred orientation of grains on the powder mounts affects the relative intensities in Table 2. The pattern for the orthorhombic form is more like that of orthoenstatite than that of protoenstatite.

Molar volumes of various assemblages with $2FeSiO_3$ bulk composition are given in Table 3 (*3*). It is clear that high pressures should favor the formation of ferrosilite over fayalite plus quartz, if the entropy change of the reaction is not greatly dependent on pressure and if the compressibilities of the two assemblages are approximately equal. Ferrosilite breaks down to fayalite plus quartz at 1000°C and 14 kb but can be synthesized from that assemblage at 1150°C and 18 kb (Table 2); hence pressure does determine the stability of ferrosilite in that temperature range. As more data on the lower stability of ferrosilite are acquired, it may be possible to extrapolate the boundary curve to low pressures, thus providing a check on Bowen's suggestion of possible stability at 1 atm. The molar volume of fayalite plus coesite is closely similar to that of ferrosilite (Table 3), and whereas ferrosilite has been synthesized in the low-pressure portion of the coesite stability field (*4*) (1400°C, 40 and 45 kb), it is possible that fayalite plus coesite might be stable at some higher pressures. Ferrosilite is expected to break down once the field of $Fe_2SiO_4$ spinel is reached (*5*).

Table 2. Preliminary x-ray data for ferrosilite: unfiltered iron radiation; silicon internal standard; $\theta$ is the Bragg angle of reflection.

| $2\theta$ (FeK$\alpha$) (deg) | $I$ | $hkl$ |
|---|---|---|
| | *Monoclinic polymorph* | |
| 17.22 | 4 | 110 |
| 24.27 | 6 | 020 |
| 33.64 | 8 | 021 |
| 34.85 | 8 | 220 |
| 37.22 | 10 | 221 |
| 38.86 | 6 | 310 |
| 43.64 | 3 | 131 (?) |
| 43.80 | 2 | 202 (?) |
| 45.93 | 2 | 002 |
| 46.02 | 2 | 221 |
| 53.22 | 2 | 331, 330 |
| 56.70 | 2 | 041 |
| | *Orthohombic polymorph* | |
| 17.17 | 7 | 120 |
| 24.21 | 10 | 020 |
| 33.66 | 4 | 121 |
| 34.81 | 7 | 420 |
| 37.75 | 1 | 321 |
| 38.85 | 9 | 610 |
| 41.22 | 2 | 421 |
| 43.78 | 2 | 131 |
| 45.36 | 2 | 202, 430, 521 |
| 47.44 | 1 | 331 |
| 49.74 | 2 | 800 |
| 53.95 | 2 | 630, 502, 322, 531 |
| 58.05 | 2 | 440, 241 |

Table 3. Molar volumes of assemblages with $2FeSiO_3$ composition.

| Assemblage | Molar volume ($cm^3$/mole) |
|---|---|
| Fayalite (46.41) + quartz (22.68) | 69.09 |
| Fayalite + coesite (20.75) | 67.16 |
| 2 Ferrosilite (33.44) | 66.88 ± 1.32 |
| $Fe_2SiO_4$ spinel (42.02) + coesite | 62.77 |
| $Fe_2SiO_4$ spinel + stishovite (14.02) | 56.04 |

Data on the synthesis and stability of ferrosilite may not be of direct significance in petrology, for the only suspected occurrences of the mineral are from low-pressure environments, and iron-rich pyroxenes are unlikely to occur in the mantle. Nevertheless, optical, structural, and thermodynamic data from the $FeSiO_3$ end member will be most useful in studies of the pyroxene group. Furthermore, the behavior of ferrosilite under pressure may serve as a model for enstatite, probably an important mantel mineral, as fayalite serves for forsterite. Ferrosilite synthesized at high pressures will also be useful for stability experiments at low pressures (*6*).

D. H. LINDSLEY
B. T. C. DAVIS
I. D. MACGREGOR
*Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C.*

**References and Notes**

1. N. L. Bowen, *Am. J. Sci.* **30**, 481 (1935).
2. ——— and J. F. Schairer, *ibid.* **24**, 177 (1932); R. Schenck, H. Franz, A. Laymann, *Z. Anorg. Allgem. Chem.* **206**, 129 (1932); L. S. Darken, *J. Am. Chem. Soc.* **70**, 2046 (1948); A. Muan, *J. Metals* **7**, 1 (1955).
3. Molar volumes (calculated from unit-cell data except where noted): quartz, J. D. Dana and E. S. Dana, *The System of Mineralogy*, C. Frondel, Ed. (Wiley, New York, ed. 7, 1962), vol. 3; fayalite, H. S. Yoder, Jr., and Th. G. Sahama, *Am. Mineralogist* **42**, 475 (1957); coesite, T. Zoltai and M. J. Buerger, *Z. Krist.* **111**, 129 (1959); $Fe_2SiO_4$ spinel (from density), A. E. Ringwood, *Geochim. Cosmochim. Acta* **15**, 18 (1958); stishovite, E. C. T. Chao, J. J. Fahey, J. Littler, D. J. Milton, *J. Geophys. Res.* **67**, 419 (1962); ferrosilite, from preliminary unit-cell volume of 444 ± 17.5 $Å^3$.
4. F. R. Boyd, Jr., and J. L. England, *J. Geophys. Res.* **65**, 749 (1960).
5. A. E. Ringwood, *Geochim. Cosmochim. Acta* **15**, 18 (1958).
6. We thank P. R. Brett, D. C. Presnall, and C. A. Batten for assistance during the experimental work. P. M. Bell and F. R. Boyd, Jr., critically read the manuscript.

24 February 1964

## Group Learning of Speech Sequences without Awareness

Abstract. *Speech sequences in groups of three persons each were registered by throat microphones and voice relays. These and other automatic devices were used to program differential reinforcement of given speech sequences with a modified conditioning technique. The results show that the order of speakers in a discussion can be brought under partial experimental control with accompanying changes in the role behavior of individuals.*

A significant part of human social behavior consists of the verbal interaction of persons in small groups, and a great deal of research has been directed toward identifying and describing its basic features. Both the meaning and the physical attributes of verbal exchange have been studied as well as its implications for leadership and other aspects of group behavior (*1*).

The research reported herein is concerned with the sequence of speeches in a group discussion and the question whether this systematic property of verbal interaction, if treated as a free operant, can be manipulated through differential reinforcement (*2*). Familiar examples often noted in groups are: who talks after whom, who has the last word, who butts in, who starts off, who is silent, and so on. In contrast to previous research on verbal conditioning in individuals (*3*), in this experiment one could determine whether the conversational order of several individuals, regardless of content, could be brought under experimental control. A speech is defined as a vocalization of any duration by a given speaker. Any one speech is succeeded when another speaker begins to talk, and so on, thus defining the order of speakers. No speaker can follow or precede himself.

Speeches and speech sequences were automatically registered by the use of a Danavox throat microphone attached to each subject and a parallel Grason-Stadler voice-operated relay. With appropriate settings for gain, attack, and release time, the relay for a given subject closes only when the particular subject makes an utterance. Microphones and relays are not activated by ambient noise or bodily movements. This makes it possible to know who is talking at any given time even though subjects talk rapidly and are in a close, face-to-face arrangement. Additional switches and relays indicate not only the current speaker but the person speaking before him. Given a group of three people, there are six such sequences possible.

The automatic registration of speech sequences overcomes the serious problems of observer bias, inaccuracy, and unreliability in previous work on the operant conditioning of conversation (*4*). The equipment "decides" what speech sequence has occurred. For example, two people seemingly talking at the same time tend to generate an alternating sequence of the two, and whoever is still talking at the end, if only for an instant, is the last speaker.

A simple experimental task was used as a vehicle for group discussion (*5*). This task was a contrived game in which the subjects were told that they were to guess the order of colors on a list and to try to get as many right as possible. Each group of three subjects was seated (at random) around a table and was asked to decide as a group which one of six colors would come up on each trial. Every 10 seconds the group was given a signal to make their decision, at which time each subject had to press a button of the color chosen. When the button was pressed simultaneously by three subjects, a light of the color chosen went on in front of each subject, and then the group was informed immediately whether they were "right" or "wrong" by a tone or buzzer respectively. In the brief interval between trials subjects were asked to discuss what their next choice would be.

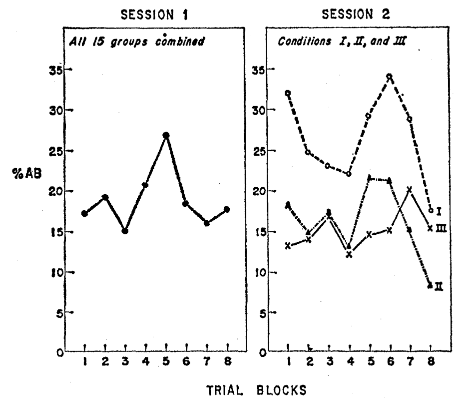


Fig. 1. Speech sequence in groups of three persons: plot of average percentage of AB speech sequences.

Unknown to the subjects, there was no list of colors. "Right" and "wrong" were determined by the speech sequence occurring immediately prior to the time of decision (button press) and not by actual colors chosen. If a particular verbal pattern occurred, the subjects were informed they made a "right" choice. Trials ending with all other verbal sequences were "wrong." The reinforcement was programmed by the equipment.

The subjects were 45 female college students and student nurses who were run in 15 groups of three persons each in two sessions of 240 trials each. The sessions were scheduled 4 to 5 days apart. Within a group, the subjects were designated A, B, and C.

In all first sessions, positive reinforcement ("right") was made contingent on the occurrence of speech sequence AB: B last speaker, A next-to-last. In the second session, three conditions were used, five groups each. In condition I, the AB pattern was positively reinforced just as in session 1; in condition II, the reversed pattern, BA, was reinforced; in condition III, the pattern CB was reinforced, that is, subject C was required to be the next-to-last speaker instead of A.

In Fig. 1, the AB speech sequences are plotted as a percentage of the six possible two-person sequences occurring in two sessions, in each of which there were eight successive blocks of 30 trials each. The pooled data of all groups in session 1 indicate that the percentage of AB sequences increased in trial blocks 4, 5, and 6 with a peak value of 27 percent in block 5. In 12 out of 15 groups the AB percentage in this block was greater than the expected 16.67 percent ($p = .035$).

In session 2, condition I shows a higher percentage of AB sequences, compared with conditions II or III, on all trial blocks. The highest average percentage of AB sequences for condition I, 34 percent, occurred in block 6 of session 2 as compared with 21 percent and 15 percent for conditions II and III ($p = .02$, Mann-Whitney test). Thus, in the five groups given the same reinforcement schedule in the second session, the desired speech sequence was maintained at a higher rate than in the control conditions. In addition, these groups yielded a higher percentage of AB sequences on most trial blocks as compared with session 1, a further indication of learning.

The effectiveness of the experimental reinforcer ("right") in controlling speech sequences appears to oscillate over time in both sessions 1 and 2. There is a peak in the learning curve and a falling off at the end. The variability may not be surprising in a human learning situation as subjects become bored with the simple activity required and solving the experimental problem takes on less significance. This is borne out by the observation that the total number of verbal acts decreases a great deal toward the last half of the session.

The evidence as a whole suggests that the verbal responses of different subjects can be linked together through differential reinforcement. The relative increase in the reinforced speech sequence (condition I) is not simply a function of higher rates of verbal activity for both A and B subjects and reduced activity for C inasmuch as the average percentage of BA sequences (the same two subjects but in reverse order) was lower in all but one trial block. Rather, subjects A and B learned to talk in the particular order AB at the end of each trial.

The learning of patterns of verbal behavior seemed to occur without subjects being aware of this regularity in their interaction. Nor is it likely that they would because such rapidly occurring sequences are hardly obvious to people participating in a discussion. In extensive questionnaire data obtained after the final session, and in probing interviews, no evidence was found that subjects had any knowledge of the nature of the experimental contingency (*3*).

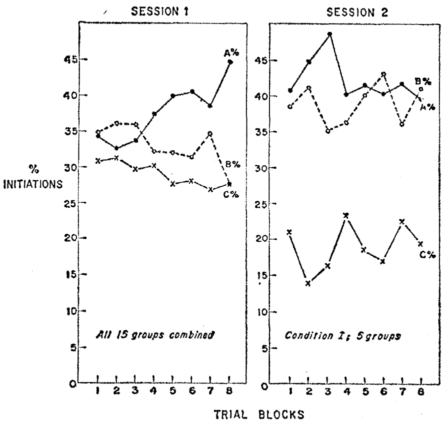


Fig. 2. Plot of average percentage of initiations made by A, B, and C subjects.

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.

DAVID SHAPIRO

*Department of Psychiatry, Harvard Medical School, Massachusetts Mental Health Center, Boston*

### References and Notes

1. R. F. Bales, *Interaction Process Analysis* (Addison-Wesley, Cambridge, Mass., 1950); J. B. Coleman, in *Mathematical Thinking in the Measurement of Behavior*, H. Solomon, Ed. (Free Press, Glencoe, Ill., 1960), pp. 7–149; J. D. Matarazzo, in *Experimental Foundations of Clinical Psychology*, A. J. Bachrach, Ed. (Basic Books, New York, 1962), pp. 473–509; J. W. Thibaut and H. H. Kelley, *The Social Psychology of Groups* (Wiley, New York, 1959).
2. Skinner outlines this approach to the analysis of social behavior in Chapter XIX, *Science and Human Behavior* (Macmillan, New York, 1953).
3. In *Behavior and Awareness: A Symposium of Research and Interpretation*, verbal conditioning is discussed together with related work on the issue of awareness in verbal learning and discrimination [C. W. Eriksen, G. A. Kimble, E. R. Hilgard, C. D. Spielberger, D. E. Dulany, W. S. Verplanck, Eds. (Duke Univ. Press, Durham, 1962)].
4. G. Levin and D. Shapiro, *J. Exptl. Anal. Behavior* **5**, 309 (1962).
5. Adapted from earlier studies of social interaction; see P. H. Leiderman and D. Shapiro, *Psychosom. Med.* **25**, 146 (1963); and D. Shapiro, *Behavior Res. Therap.* **1**, 267 (1963).
6. Experimental studies of reinforced and nonreinforced leadership roles are described by Shapiro and Leiderman in *Psychobiological Approaches to Social Behavior*, P. H. Leiderman and D. Shapiro, Eds. (Stanford Univ. Press, Stanford, in press).
7. Supported by ONR contract Nonr-1866(43), Group Psychology Branch, and by research career development award K3-MH-20,476-01, U.S. Public Health Service. I am very grateful to Bernard Tursky for designing the techniques used in recording speech sequences and to Vincent Tempone for his suggestions.

7 February 1964

## 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-