# Reports

## Subjective Evaluation and Reinforcing Effect of a Verbal Stimulus

Greenspoon (*1*) has recently shown that when subjects are instructed to "say all the words you can think of," the interposition of "Mm-hmm" by the experimenter following a particular class of responses, such as plural nouns, significantly increases the production of these responses over successive periods. He also suggests that the subjects are not aware of the contingency between their behavior and that of the experimenter. While such learning without awareness is not new in the psychological literature, the effect of such an innocuous phrase as a reinforcer has attracted particular attention.

The data reported here, which are abstracted from a larger study of subjects' reactions to reinforcing stimuli, report on a relationship between free-responding verbal behavior, the reinforcing effect of a verbal stimulus, and the subjects' evaluation of that stimulus (*2*).

A total of 28 male summer-school students were used as subjects in the verbal reinforcement experiment. They were tested individually in a small experimental room, with the experimenter seated behind the subject. Each subject was informed that this was a test of the "total available vocabulary of college students." He was requested to say all words that he could think of, not to repeat words, not to count or to give phrases or sentences. All responses were recorded on tape. In the reinforcement period, the experimenter emitted the reinforcing interjection "Mm-hmm" immediately after every plural-noun response. All subjects gave 500 responses before they were stopped. The first 100 responses were used to obtain the operant level of plural-noun responses, and no responses were reinforced. During the next 200 responses, all plural nouns were followed by the reinforcing stimulus. During the last 200 responses, no reinforcements were given in order to obtain extinction data.

After the response session, all subjects were given an extended interview to determine the subjects' reactions to the reinforcing situation (*3*). This interview consisted of 30 open-ended questions which began with a general "What did you think about during the experiment?" and led to specific questions whether the subject was aware of the contingency between his production of plural nouns and the behavior of the experimenter.

The responses of all subjects to the interview were scored on a scale of 1 to 11, with a score of 1 representing full awareness of the reinforcing contingency and 11 representing a complete lack of awareness. Full awareness was defined as a description by the subject of the contingency between the plural noun response and the experimenter's behavior, while complete unawareness required that the subject verbalize no hypothesis concerning this contingency. The obtained awareness values ranged from 3 to 11 with a mean of 5.9, and a rater reliability of 76 percent. The mean rating of 6 indicates that the average subject verbalized some secondary hypothesis that there might have been some unknown relationship between his associations and the experimenter's behavior. None of the subjects, however, was able to state specifically what the contingency was.

All subjects were aware of the fact that the experimenter did say "Mm-hmm" every now and then. In the course of the interview they were asked what they thought this behavior indicated. On the basis of this question they were divided into two groups, a positive and negative group. The positive group consisted of those subjects who thought that the reinforcer had positive aspects, that it meant they were doing all right, that it was encouraging them to go on. The negative group thought that the reinforcer had negative aspects, that it meant they were going too fast, giving the wrong kinds of words. Many of these subjects would stop after the first occurrence of the reinforcer as if they were expecting further instructions. The mean awareness values for these two groups were 6.4 for the positive group and 5.6 for the negative group, showing no significant difference between the two groups on this variable.

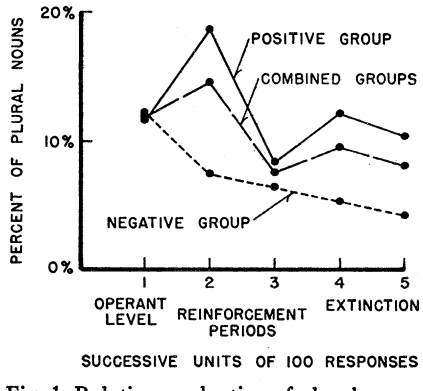


Fig. 1. Relative production of plural nouns during successive response periods.

Figure 1 shows the effect of the reinforcer on the production of plural nouns. The dependent measure used was the percentage of plural nouns out of total nouns given in any 100-word period. This relative index of plural-noun production was used because the production of all nouns (singular and plural) was affected by the reinforcing stimulus. Figure 1 shows little effect of the reinforcer on the relative production of plural nouns when all subjects are combined. While there is a slight increase in the first reinforcing period, this increase is not significant. When the positive and negative subjects are separated, however, there is a clear difference between the two groups. The positive group shows a significant increase in plural-noun production during the first reinforcing period ($p < 0.05$), while the negative group shows a decrease. The difference between the two groups in the first reinforcing period is, of course, significant ($p < 0.01$). In the subsequent periods, however, no such difference appears. The positive group returns to below operant level in the second reinforcing period and changes little from then on, while the negative group continues to decrease.

The effect in the initial reinforcing period shows a clear relationship between the subjects' evaluation of the reinforcing stimulus and the effect of that stimulus on their verbal behavior. A positively evaluated stimulus operates as a positive reinforcer, while the same stimulus has a negative reinforcing effect if the subject evaluates it as a negative stimulus. Since there are no differences in the awareness of the subjects in the two groups, this effect cannot be simply ascribed to some cognitive response to the contingency in one group which is absent in the other. It is also difficult to ascribe the difference between the two groups to some simple mediating judgment. None of the subjects said that, because the reinforcer was encouraging or discouraging, he reacted or decided to react by increasing or decreasing the particular association or response that preceded it. Some such mediating process may of course have taken place during the experiment. If it did, the subjects could not recall it by the end of the session.

The results of this study indicate that, in human verbal learning, the subjects'

subjective evaluation of the reinforcing stimulus may provide an independent measure of the reinforcing value of a verbal reinforcer.

GEORGE MANDLER
WARREN K. KAPLAN
*Department of Social Relations, Harvard University, Cambridge, Massachusetts*

References and Notes

1. J. Greenspoon, *Am. J. Psychol.* 68, 409 (1955).
2. This study was supported by an undergraduate research grant from the Social Science Research Council and by a grant from the Center for International Studies, Massachusetts Institute of Technology.
3. We would like to thank Sherman Tatz for the use of the questionnaire which he developed for a similar study.

8 August 1956

## Influence of "Aging" on the Characteristics of an Electrodeless Discharge

"Aging" of a freshly prepared discharge tube—that is, maintaining the discharge for a period of time—at a constant applied potential $V$, has been found to affect the discharge characteristics markedly. The influence of aging on the conductivity of a low-frequency electrodeless discharge in iodine vapor is reported here. The details of the experimental set up are similar to those reported earlier by Saxena and me (*2*).

Aging decreases the discharge current $i$ and the "threshold potential" $V_m$, namely, the potential at which the discharge becomes self-maintained. The conductivity decreases (i) very rapidly during the first few minutes, (ii) less rapidly during the next few minutes, and (iii) slowly until it attains saturation. Figure 1 shows a typical plot of the discharge current $i$ versus time $t$ in minutes. The equation proposed by Saxena *et al.* (*3*) ($\delta i = kt^{1/m}$) for similar observations in water vapor and iodine vapor under ozonizer discharge seems to hold good only during the afore-mentioned period (ii).

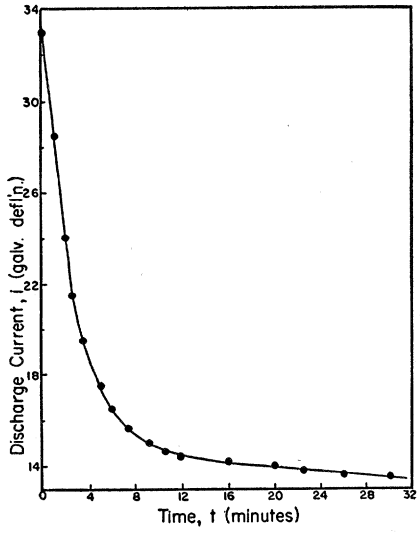


Fig. 1. Variation of discharge current with time.

The decrease of the threshold potential on aging was observed even in the presence of excess of solid iodine and therefore cannot be ascribed to the pressure drop caused by adsorption of the vapor on the walls of the vessel. Aging reduces the width of the period of the discharge which is not self-maintained. In a particular experiment, the potential in the period that was not self-maintained was between 0.79 and 1.33 kv before aging, while it was between 0.79 and 1.06 kv after aging. Furthermore, aging is effective only when it is carried out at $V > V_m$; aging at $V < V_m$ has no appreciable effect on the discharge characteristics.

C. N. RAMACHANDRA RAO
*Department of Chemistry, Purdue University, West Lafayette, Indiana*

References and Notes

1. The work described was undertaken in the physicochemical laboratories of the Benares Hindu University, Benares, India. My thanks are due to S. S. Joshi for his kind interest in the work.
2. A. P. Saxena and C. N. Ramachandra Rao, *J. Sci. Research, Agra Univ.* 3. 207 (1954.)
3. A. P. Saxena, M. G. Bhatawdekar, N. A. Ramaiah, *Nature* 171, 929 (1953).

1 August 1956

## Preparation of Pure Hydroxyapatite Crystals

Naturally occurring hydroxyapatite exhibits a variable composition and contains impurities that have unknown effects on the structure and properties of the basic compound. A simple method for the production of pure, well-crystallized hydroxyapatite has long been needed. Methods of synthesis for this mineral have been reported in the past (*1*), but all of them produced impure and poorly crystallized products. This communication describes the preparation of pure hydroxyapatite suitable for x-ray diffraction, single-crystal studies.

The procedure is similar to an early preparation of hydroxyapatite by the hydrolysis of brushite ($CaHPO_4 \cdot 2H_2O$) (*2*). In the method outlined here, monetite ($CaHPO_4$), instead of brushite, is hydrolyzed to hydroxyapatite in a closed system. The reaction involved is probably one, or both, of the following.

$$10CaHPO_4 + 2H_2O \xrightarrow{300°C} Ca_{10}(PO_4)_6(OH)_2 + 4H^+ + 4H_2PO_4^- \quad (1)$$

$$14CaHPO_4 + 2H_2O \xrightarrow{300°C} Ca_{10}(PO_4)_6(OH)_2 + 4Ca^{++} + 8H_2PO_4^- \quad (2)$$

An orthophosphoric acid solution (1 vol of reagent-grade 85-percent $H_3PO_4$ to 5 vol of distilled water) was saturated at room temperature with reagent-grade tribasic calcium phosphate. Well-crystallized $CaHPO_4$ was precipitated from the clear saturated solution by heating the solution nearly to its boiling temperature. The $CaHPO_4$ was filtered from the hot solution, washed thoroughly with distilled water, rinsed with absolute alcohol, and finally dried at 105°C. From 0.5 to 1.0 g of $CaHPO_4$ may be obtained from 100 to 150 ml of the saturated solution.

Pure well-crystallized $Ca_{10}(PO_4)_6(OH)_2$ was prepared from the reaction of 0.1 g of the $CaHPO_4$ with 10 ml of distilled water in a platinum-lined, Morey-Ingerson type hydrothermal bomb (*3*) at 300°C for 10 days. During this time, the system had an internal pressure of about 1250 lb/in.$^2$ owing to the vapor pressure of saturated steam at 300°C.

To obtain a complete reaction, it was necessary to use at least 10 ml of water for each 0.10 g of $CaHPO_4$. Less than this ratio of water to $CaHPO_4$ resulted in a mixed product of $Ca_{10}(PO_4)_6(OH)_2$ and $CaHPO_4$. Apparently the controlling factor for the hydrolysis is the final $p$H of the liquid. As long as this $p$H stays above 2.0 to 2.5, the reaction will proceed in the desired direction. Below a $p$H of about 2.0, the stable solid phase is $CaHPO_4$ for the reaction conditions used.

The presence of certain cation impurities can strongly influence the final product. During some preparations, the platinum lining developed cracks and Fe and Cr ions from the steel bomb were introduced into the water. When this happened, the final product contained a large proportion of well-crystallized whitlockite [$\beta$-$Ca_3(PO_4)_2$].

Under normal conditions, well-developed clear hexagonal dipyramidal crystals of hydroxyapatite, which range up to about 0.3 mm in length, are produced. A spectrographic analysis showed the following amounts of impurities: 0.01–0.1 percent = Cu, Fe, Na, Pb, Si, Sr; 0.001–0.01 percent = Al, Ba, Cr, Mg, Ni, Pt; 0.0001–0.001 percent = Ag, Mn.

A petrographic examination showed the crystals to be uniaxial negative with indices of refraction: $\varepsilon = 1.643 \pm 0.002$ and $\omega = 1.649 \pm 0.002$.

A method has been reported by Hayek, Lechtleitner, and Böhler (*4*) for obtaining well-crystallized hydroxyapatite by heating a finely divided hydroxyapatite with NaOH solution in a hydrothermal bomb. Although these investigators obtained well-formed crystals, the product was not as pure as might be desired, for these crystals contained at least 0.5 percent Na (*5*). Also, no attempt to remove the carbonate ion was made by Hayek and coworkers, and the influence of car-