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PROGRAMMED LEARNING OF A SECOND LANGUAGE.

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THE PROCESSES OF EXPERIMENTAL PROGRAMING OF A FOREIGN LANGUAGE ARE EXAMINED ACCORDING TO THE PRINCIPLES OF OPERANT CONDITIONING, WHICH IS THE BASIS OF PROGRAMING TECHNIQUES. DISCUSSION OF FORMAL REPERTOIRES COVERS THE USE OF SUCH CONDITIONING METHODS AS DISCRIMINATION LEARNING AND TRANSFER, STIMULUS GENERALIZATION, RESPONSE GENERALIZATION, AND ECHOIC BEHAVIOR TO TEACH STUDENTS TO IMITATE, TRANSCRIBE, READ, AND TAKE DICTATION IN THE TARGET LANGUAGE. THEMATIC REPERTOIRES ARE DISCUSSED IN TERMS OF INTRAVERBAL RESPONSES, TACTS, AND MANDS. CHARTS ARE FOUND THROUGHOUT THE ARTICLE FOR CLARIFICATION OF MATERIAL. ALSO INCLUDED ARE A SUMMARY TABLE OF AVAILABLE LANGUAGE PROGRAMS AND A SIX-PAGE LIST OF REFERENCES. THIS ARTICLE APPEARED IN THE "INTERNATIONAL REVIEW OF APPLIED LINGUISTICS IN LANGUAGE TEACHING," VOLUME 2, NUMBER 4, NOVEMBER 1964, PAGES 249-301. (AF)

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PROGRAMM"D LEARNING OF A SECOND LANGUAGE

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PROGRAMMED LEARNING OF A SECOND LANGUAGE

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Les processus de l'apprentissage programmé d'une langue étrangère sont examinés selon les principes du conditionnement opérant qui est à la base des techniques de la programmation. Les méthodes utilisées dans divers programmes afin de conditionner des répertoires formels (imitation, transcription, lecture et dictée) et des répertoires thématiques (traduction, appellation, interrogation, etc...) sont interprétées selon l'évidence expérimentale pour les processus de comportement impliqués : discrimination des stimuli et différenciation des réponses.

Das programmierte Erlernen einer Fremdsprache wurde in vorliegendem Beitrag im Rahmen der wirksamsten Konditionierung auf der Basis der Programmierungstechnik untersucht.

Vf. prüft dabei die in einer Vielzahl von Programmen verwendeten Methoden zur Konditionierung formaler Sachgebiete (Nachahmung, Transkription, Lesen und Diktataufnahme), sowie thematischer Sachgebiete (Übersetzung, Begriffseinordnung, Fragestellung etc.).

Diese Untersuchung erfolgt im Hinblick auf den klaren Einfluß des Sprachlabors auf die Verhaltensweise des Schülers : Unterscheidung von Stimulanten und Differenzierung der Antworten.

INTRODUCTION

The cardinal requirement of programming, "specify the terminal behaviors", has nowhere had a more salutary effect on educational technology than in the area of second-language learning. Although language pedagogy turned to linguistic science for these specifications over two decades ago, the later arrival of programmed instruction emphasized, and placed a new perspective on, the contribution of descriptive linguistics. The new emphasis is that linguistic specifications are a *sine qua non* for the conditioning enterprise; they codify group norms for verbal behavior in the relevant language community and, therefore, provide the programmer with criteria for acceptable forms and sequences of responses. The new perspective is that a linguistic analysis of terminal behaviors is not a prescription for second-language learning, this is the task of the programmer.

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1) The preparation of this article and certain of the experiments reported herein were supported in part by a contract with the Language Development Section, U. S. Office of Education. I am indebeted to F. R. Morton and A. B. Gaarder who inspired and financed, respectively, my interest in second-language learning, and to D. M. Brethower, G. L. Geis, R. Glaser, and S. Sapon for helpful suggestions concerning this article.

The good fortune of the language programmer (and student) in finding an entire discipline devoted to the systematic specification of terminal behaviors is overreached by an even greater fortune: the techniques of the laboratory analysis and control of behavior, upon which programming is based, are more literally applicable to the conditioning of second-language behavior than to most of the other repertoires that programming has confronted. The objectives of most programs are restricted to changing the written, verbal behavior of a student in response to textual stimuli. The prerequisite motor responses and discriminations among orthographic stimuli have already been conditioned and are taken for granted. The behaviors involved in reading and understanding English and in writing at least a "reasonable" answer are also assumed. As Gilbert (1962) has put it: "Our student is not a master of the subject because he cannot make the mastery responses on the right occasions, not because he is unable to make those responses at all ... The responses of mastery are there..." (p. II). This type of verbal conditioning, involving a restructuring of the student's highly articulate first-language repertoires, has a limited resemblance to laboratory research on the control of behavior. Transitional behavior effected by shifting contingencies of reinforcement, patterns of discriminative stimuli, or both, is little studied and poorly understood in comparison with the shaping, maintenance, and extinction of behavior in initially naive organisms.

The programming task of restructuring an extant verbal repertoire may be contrasted to that of conditioning second-language fluency. In the latter case, there is nothing extrapolative in the application of laboratory techniques and nothing metaphorical in the use of concepts gained from a functional analysis of behavior in the laboratory. New discriminations (auditory, textual) must be conditioned, new forms of response (vocal, written) must be differentiated, concurrent responses of differing topography must each be brought under the control of appropriate discriminative stimuli, novel chains of topographically novel responses must be established, and so forth. These behaviors must be conditioned largely *de novo,* although it is never possible, as we shall see, to overlook sources of interference and enhancement from the first-language repertoires.

Two other developments augur well for the success of second-language programming. The interest of the communication sciences in verbal, especially vocal, behavior has led to a greater sophistication and instrumental capability in describing and analyzing the vocal response than is available for any other behavior (Fant, 1958). These disciplines have also contributed significant techniques and data toward an understanding of the listener's behavior as well as that of the speaker (Licklider and Miller, 1951). Another source of methods and findings for the control of verbal behavior is less well developed but bound to have equal or greater impact on language pedagogy; this is the rapidly growing discipline of psycholinguistics (Saporta, 1961).

If second-language programming is aided by these four "sources of strength", it also has four countervailing antecedents in language pedagogy which must be set aside: an unsuitable model of learning, undue emphasis on language aptitude, subjective evaluation of student performance, and incompetent classroom research.

The language teacher has operated frankly with a sunburn model of learning (Lane, 1962c) and his techniques are as inefficient as this characterization of learning is inappropriate. The teacher, prime source of knowledge, light (and, occasionally, heat) "exposes" students to the language and its principles. He is aided in this endeavor by the language laboratory, now a commonplace in secondary education (Morton, 1961b), which also exposes the students to the material in limited doses; 20 minutes is generally considered the maximum safe exposure in one treatment. When classroom practices permit active participation by the student at all, it is usually in the form of repetitive drills which are presumed to "fix" or "stamp in" the material through repetition alone. The "brighter" students "soak up" the material and become "enlightened." Dull students, who fail to learn, are simply not "sensitive" or "receptive."

The remarkable plasticity of behavior is ignored by this model. Instead of acknowledging that the inadequacies of the students are the product of inadequate technique, and then spending all effort to improve technique, teachers often assign the key role in language learning to ability or endowment, and thus place the process beyond their control — and responsibility. The construct "language aptitude" is the *deus ex machina* that spares the language-learning story its tragic ending. In constructing so-called aptitude tests, psychologists have not helped to refocus attention on the critical variables, the manipulable variables, in language-learning. Indeed, since it is invariably true that the student who takes the test is assigned an aptitude score, the presence of the score lends credence to the reality of aptitudes. This gambit has as much practical effect as lifting oneself by one's own bootstraps, and leaves the language teacher in about the stance implied. The naive assumption that aptitude tests measure innate capacity is no longer acceptable. As one noted student of individual differences points out, "It should be obvious that all psychological tests measure the individual's current behavior, which inevitably reflects the influence of prior learning" (Anastasi, 1961, p. 425). The task of the language teacher or programmer is to destroy the test — retest reliability of language aptitude tests.

Evaluations of pedagogical techniques in second-language learning are most often grossly multi-dimensional, idiosyncratic and subjective. "The objectives of foreign language study still include such goals as understanding the foreign culture, appreciating the great works of literature in the language, increasing English vocabulary, learning about grammar — Latin even taught us how to think!" (Sapon, 1963). The merit of multiple and complex objectives such as these is that the inadequacy of language pedagogy in attaining them cannot be assessed; thus, "achievement" in these areas may be offered as mitigating the limited effect of the teacher in conditioning the language behaviors themselves. Even when the objectives are somewhat more circumscribed, as "a spoken command of the language," the criteria for an acceptable response include such notions as phonetic accuracy, response latency, intonational accuracy, appropriateness of vocabulary, richness of vocabulary, use of idioms, propriety of style, etc. Only rarely has the criterion behavior been adequately specified, and even under those circumstances, the assessment device usually involves a panel of judges and is heir to the traditional problems of inter- and intra-judge reliability and validity.

Prior research on second-language learning [2]) has been, with few exceptions, seriously inadequate. Carroll (1962) seems to damn it all, in an extensive survey of research in this area, by concluding with the faint praise: "it is clearly within the realm of possibility that the results of such research could make language teaching more effective and efficient" (p. 52).

The inadequacies of the research are multiple. "Whereas psychologists perform experiments with insufficient relevance to foreign language teaching, members of the foreign language teaching profession perform studies with insufficient experimental rigor" (Carroll, 1962, p. 9). Even when relevance and rigor have prevailed, studies in this area have suffered the many evils of comparison-group designs (vide Lane, 1961). Furthermore, the comparison is usually among the effects of complex experimental treatments, many-faceted and extending over many months, evaluated all too often either anecdotally or by tests of doubtful validity and reliability. These properties of the experimental method are in part the result of competing pedagogical and research objectives in the classroom setting. As a consequence, the findings of even the most carefully executed studies have little generality. No wonder that Carroll (1960) finds no research basis for educational policy on foreign language teaching: "However sympathetic we may be to [current] recommendations, they are often based on assumptions about which the most charitable thing to say is that they have not been proven" (p. 137).

The character of current second-language programming reflects these several antecedents. Many programs draw extensively from the findings of linguistics, both in specifying the terminal behaviors and in determining sequencing based on a contrastive analysis of the student's first and second languages. A few have systematically applied laboratory techniques for the control of behavior. A lesser number reveal the impress of findings in the communication sciences, especially in acoustic phonetics; psycholinguistics has had little impact as yet. Finally, many programming efforts have inherited the tradition of educational research in language pedagogy. The program is admixed with arbitrary amounts of classroom and language-laboratory instruction and drill and the effects of the complex enterprise are compared in cursory fashion with those of more traditional methods. The failure to provide a detailed account of the termi-

[2]) See Carroll (1963), Nostrand (1962) and Pimsleur (1960).

nal repertoires actually attained by students who have completed the second-language program is almost universal.

The present discussion of the basic research underpinnings and applied findings in second-language programming proceeds in terms of a functional analysis of verbal behavior (Skinner, 1957). The discussion is *behavioral,* because the objective of second-language programming is to condition certain terminal behaviors (largely spoken and written); the discussion draws heavily on a *functional analysis,* because it is this analysis which describes the relations between the antecedents and consequences of behavior and the behavior itself; we must know these controlling relations if we are to arrange effective and efficient second-language learning.

A functional analysis of the terminal behaviors for a second-language program will usefully distinguish between *formal* repertoires, in which there is a point-to-point correspondence between stimulus and response, and *thematic* repertoires in which responses are controlled by common sets of variables but without formal correspondences (Skinner, 1960). The student (or child) who has learned only to imitate, read, and copy in a new language has acquired purely formal repertoires; the topography of his behavior in each case shows a point-to-point correspondence to the form of the stimulus conditions. However, he is as yet unable to respond appropriately to the nature of the stimulus conditions and this lack of thematic repertoires leaves him unprepared to join the verbal community. In sum, he knows *how* to say things but he does not know *what* to say. Talking birds, mimics, typists, and stenographers may earn their keep by purely formal repertoires, but most adult verbal behavior reflects both formal and thematic sources of strength. Thus, the terminal behavior of the student will be determined both phonetically (or orthographically) by the audience and thematically by the environmental conditions.

The distinction between the two repertoires may be sharpened by noting that a minimal unit of behavior may be identified for a purely formal repertoire and formal repertoires may therefore be extended readily to new stimuli. The minimal unit may be the phoneme or the grapheme or it may be even more fragmentary. Once these stimulus-response units are made available through the conditioning of a formal repertoire, the student can respond adequately to novel stimuli by responding piecemeal — that is, with a series of unit responses never before arranged in that order. For example, minimal command of the formal repertoire involved in reading English text permits a passable attempt at, say, "marmoset," but nothing in the thematic repertoires that the student may have acquired previously enables him to say "marmoset" in the presence of marmosets, to make statements about marmosets, and so forth. The ability of formal repertoires to be extended to new stimuli is predicated on the availability of minimal units which require, in turn, the point-to-point correspondence of stimulus and response that characterizes these repertoires.

FORMAL REPERTOIRES

We may subdivide the formal repertoires involved in second-language learning according to whether the stimulus and the response are each written or spoken. The distinction is important not only because the two classes of stimuli have different modalities and the two classes of responses have different topographies, but also because the four possible functional relations have different dynamic properties. When both stimulus and response are spoken, we term the behavior *echoic;* the name implies the point-to-point acoustic correspondence which characterizes this repertoire. In *transcription,* both stimulus and response are written. In *textual* behavior, a spoken response is controlled by a written stimulus. In *dictation,* the stimulus is spoken, the response written. In each of the first two formal classes, the stimulus and the response have similar form, acoustic or visual, but in all four classes it is possible to predict the response given the stimulus or to infer the nature of the stimulus if the response is known; this is another way of stating the point-to-point correspondence between stimulus and response that defines a formal repertoire.

Each of the four formal repertoires obviously requires that the student make different responses to physically different stimuli; it is perhaps less obvious that he must more often make the same response to different stimuli; different fonts of type typically evoke the same textual behavior, differing rates of speaking the same transcriptions, and so forth. When the properties of responding change following a change in the stimulus, we speak of stimulus discrimination; to the degree that responding remains invariant under this change, we speak of stimulus generalization. The first requirement of a formal repertoire, then, concerns stimulus control: there must be generalization within arbitrarily defined classes of stimuli and discriminations between these classes. The second requirement concerns the properties of responding: response topography must show small, systematic varia turn within arbitrarily defined classes and large and abrupt changes from one class to the next. The third requirement of a formal repertoire concerns the coordination of changes in the stimulus with changes in the response. To take an example from a textual repertoire in English, in order to read the pair of words "pin pan," these requirements must be met: (1) the orthographic symbol "i" must be visually discriminated from "a," etc., but generalized with "*i*," "I," and that letter in various type fonts; similar requirements apply to "a" and to the other letters. (2) response topography must include distinct response classes such as [ph], [ɪ], and [æ] but there is also a range of permissible and necessary variation within each class; thus, the reading of "pin" may range from [p^hɪn] to [p^hɪ:n] or to [pɪn]. (3) [p^h] must occur in the presence of initial "p," [ɪ] in the presence of "i," and so forth. Even if the letters "i" and "a" are *discriminated* and the responses [ɪ] and [æ] are *differentiated,* without the *coordination* required the textual behavior would be incorrect (e.g., [p^hæn – p^hɪn]).

Before considering each of the four formal repertories, the sections that follow describe some recent experiments on discrimination, differentiation, and coordination. Laboratory research on these behavioral processes provides methods and findings that may be used to arrange their acquisition in second-language programming.

Discrimination learning and transfer

The acquisition and maintenance of stimulus discriminations have been studied extensively with human and infra-human organisms in the psychological laboratory. These experiments involve most often stimuli that are synthesized in the laboratory and varied along a single dimension, such as pure tone frequency. Controlled experiments on discrimination learning with synthetic stimuli varying in serveral dimensions, or with stimuli from "natural language" (spoken or written), are rare. A description of four representative experiments will illustrate methods and findings that are relevant to the programming of second-language discriminations involved in the formal repertoires.

In a series of experiments on discrimination learning with speech stimuli in a second language, Lane (1964b) has observed extremely rapid acquisition of differential stimulus control, suggesting the transfer of the subject's first-language discriminations. When a Spanish phoneme was presented as S^D (a stimulus correlated with reinforcement for responding) and a variety of English approximations were presented as S^{Δ}s (correlated with nonreinforcement), the subjects stopped responding to S^{Δ}s after the first few presentations.* Indeed, most of the errors in learning were due to "over-discriminating," that is, failing to repsond to the allophonic variants of S^D throughout the sequence of stimuli. In one study, a self-instruction program was prepared to teach discriminations among the vowels and consonants of Spanish. The program was subdivided into 14 frames, each of which included allophones of a particular Spanish phoneme (S^D) and those of other English and Spanish phonemes (S^{Δ}'s). The 14 frames as well as the 60 stimuli within each frame were sequenced according to a tentative schedule of difficulty for the English-speaking student. When the subject responded (button-press) to an S^D or failed to respond to an S^{Δ} during the 4-sec interstimulus interval, a point was added to a counter in front of him. Failing to respond to S^D, or a response to an S^{Δ}, cost him a point. Figure 1 shows that most of the frames in this program were mastered to a criterion of eight or less errors in a single trial. These data and others reported suggest that discrimination learning among the sounds of a second-language, at least one within the same family as the subject's native language, may be expected to pro-

* [Editor's] note For a slightly expanted discussion of the role of S^D and S^{Δ} in operant conditioning, the reader is referred to Professor J. B. Carroll's "Primer of programmed instruction in foreign language teaching" in *IRAL* 1963, 1, p.124. Cf. also A. P. van Teslaar. "Les domaines de la linguistique appliquée, – II", IRAL, 1963, 3–4, p. 234 ff. for further references to conditioning theory.

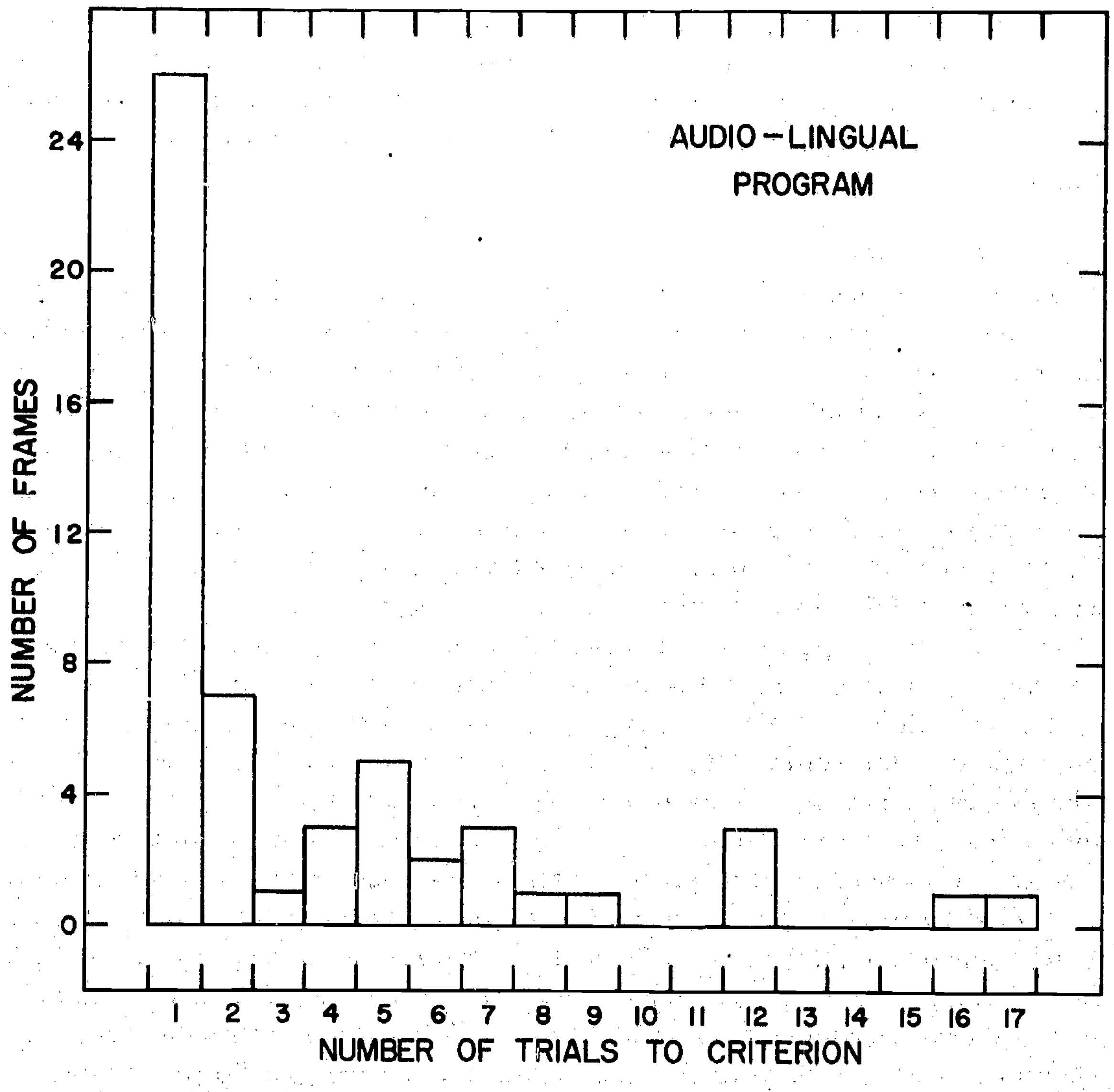

Figure 1. Discrimination learning of Spanish phonemes with an audio-lingual program. The average number of frames in which three subjects reached criterion within one through 17 trials. (From Lane, 1964 b.)

ceed quite rapidly when conditions are optimized because the subject transfers first-language discriminations to the new task. Additional support for this conclusion was obtained when the program described above was administered without reinforcement both before and after programmed learning. For each of the 14 frames, Fig. 2 shows the number of errors made during programmed learning plotted against the percent increase in correct responses from the pre-test to the post-test. There are some frames for which the increase in the percent of correct responses on the tests is small and so is the number of errors during programmed learning. These frames, represented by points at the lower left of Fig. 2, evidenced a high baseline of discrimination which is presumably the

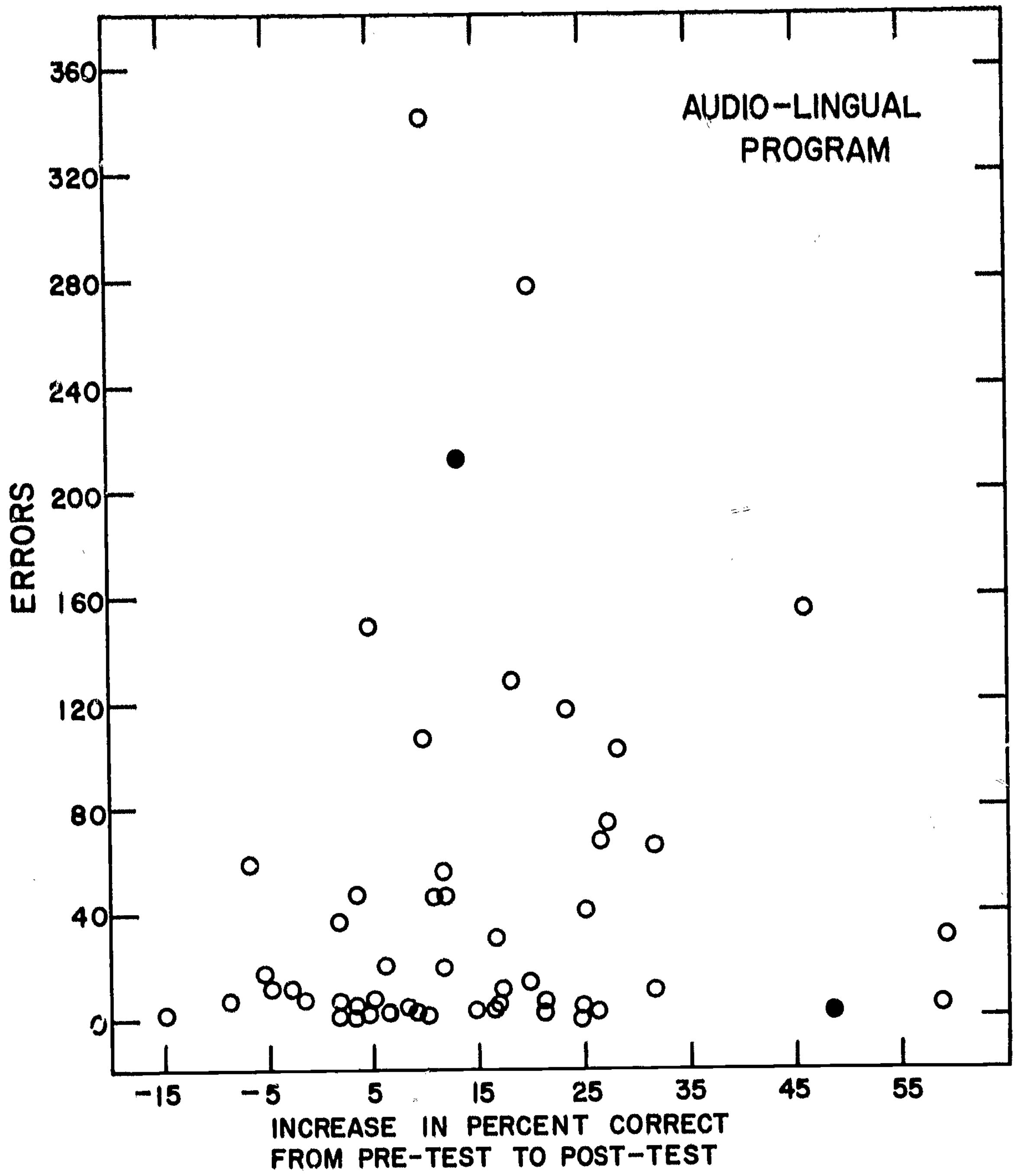

Figure 2. Discrimination learning with an audio-lingual program. For each of 14 frames, the number of errors made during discrimination training is plotted against the percent increase in correct responses from a pre-test to a post-test, in which the program was administered without reinforcement. (From Lane, 1964b.)

largesse of first-language learning. For further evidence of the transfer of first-language discriminations, consider the frames, represented by points toward the lower right of the figure, for which there was a large increase in percent correct on the tests following a period of learning with relatively few errors. Figure 3 permits a closer look at the time-course of discrimination learning during one of these frames (the one showing a 47 percent increase in accurracy). This graph of cumulative correct responses to successive stimuli shows that the subject responded to the first S^D (as instructed), then failed to respond to the next two presentations of S^D, and responded correctly thereafter. The abrupt increase to near-perfect performance after but a few errors represents the transfer rather than the acquisition of a discrimination; it has been called "concept attainment" in other quarters.

The transfer of first-language discriminations, reflected by the function in Fig. 3, may be contrasted with the more rare case of genuine acquisition of a

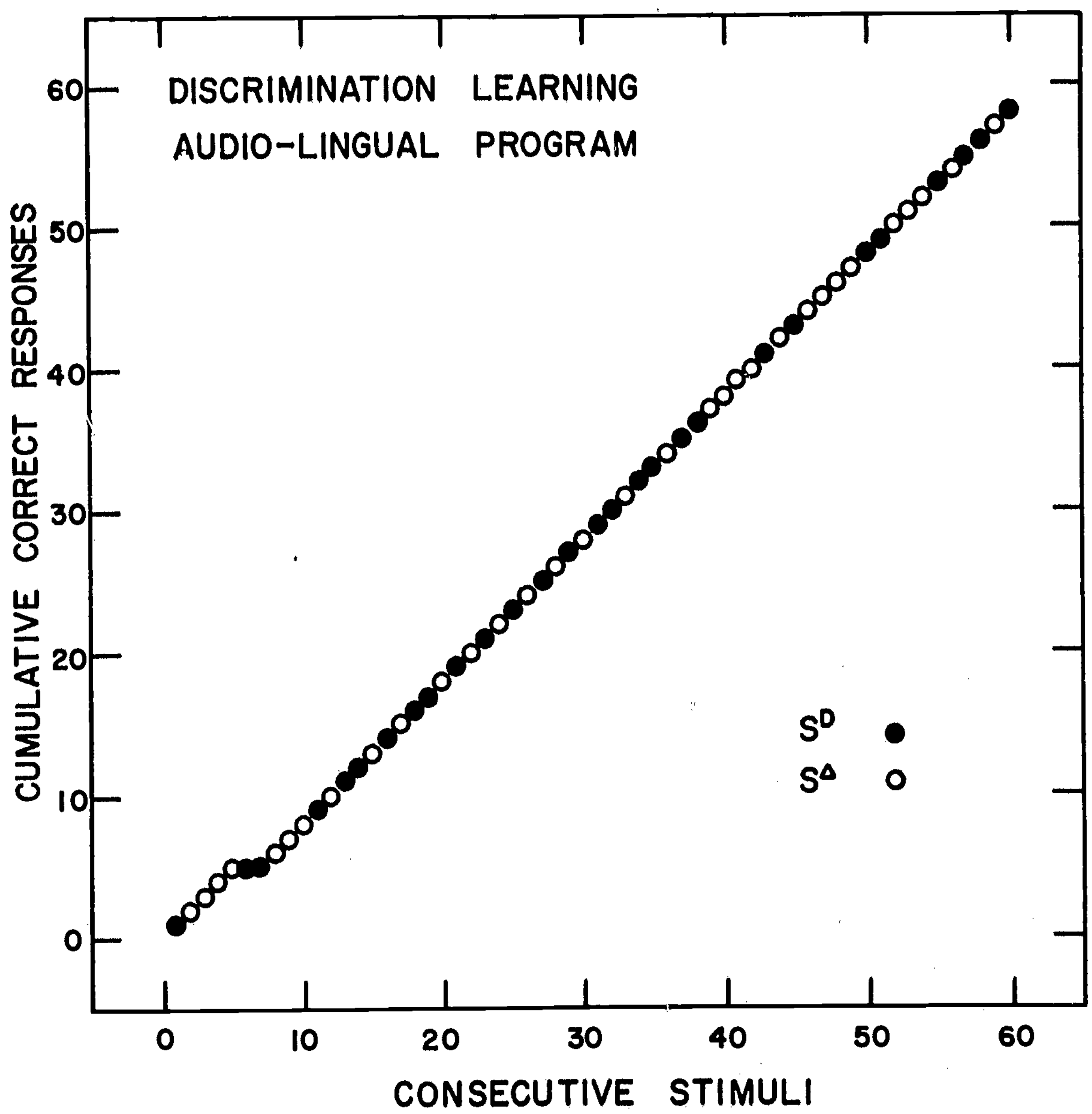

Figure 3. Transfer of discrimination in an audio-lingual program. Cumulative correct responses to consecutive stimuli by one subject. (From Lane, 1964 b.)

speech discrimination, shown by the cumulative curve in Fig. 4, obtained from the same subject. This graph corresponds to the filled circle toward the top of Fig. 2; the numerous errors during discrimination learning are evident but they were not in vain, for the subject's post-test revealed a 15 percent increase in accurracy. In this frame, which involved the trilled Spanish /r̃/ in intervocalic position as S^D and the English /r/ in that position as S^Δ, we see the more gradual development of differential stimulus control that is normally associated with the process of discrimination learning.

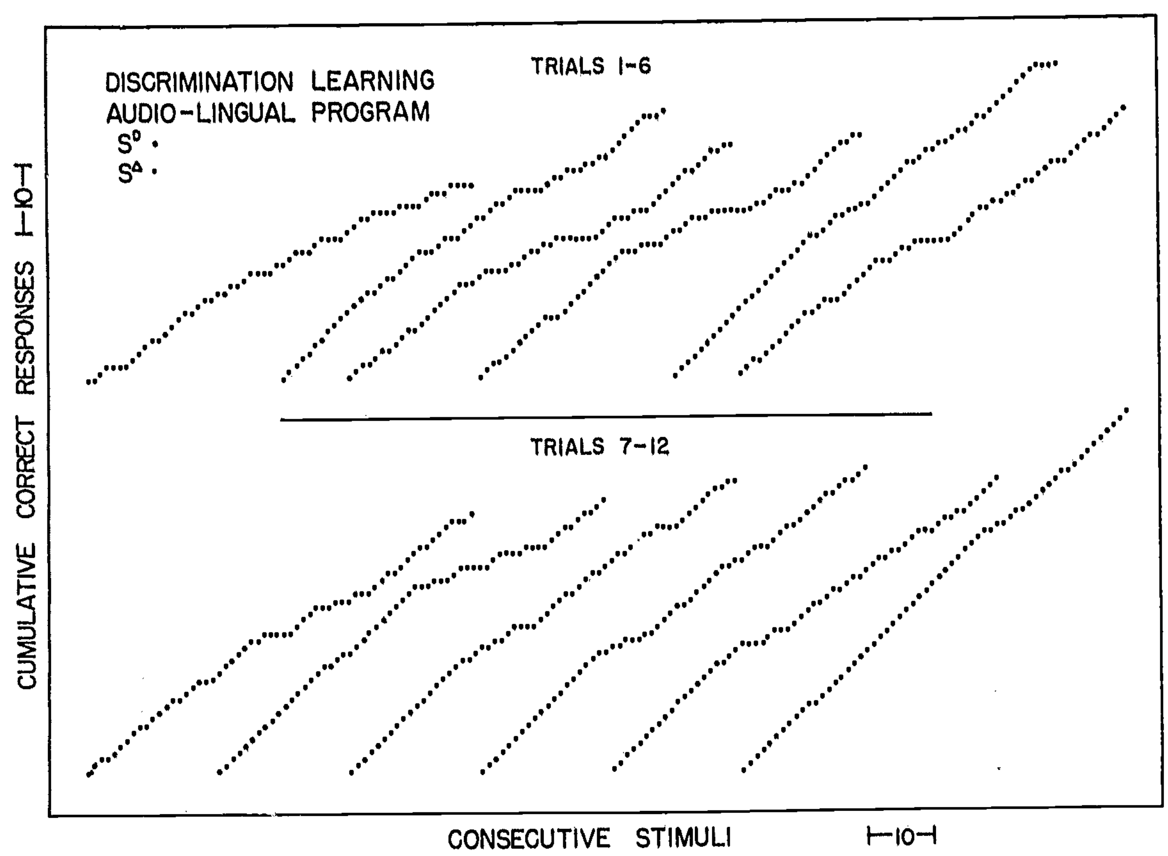

Figure 4. Acquisition of discrimination in an audio-lingual program. Cumulative correct responses to consecutive stimuli by one subject during 12 trials. (From Lane, 1964b.)

Suppes et al. (1962) have performed several studies of discrimination among Russian phonemes and have examined the fit of mathematical models to the observed time-course of discrimination learning. In one study, a basic list of Russian syllables was constructed with 32 initial consonant phonemes and 5 vowels. The 144 syllables were grouped into contrasting pairs, differing only in the initial consonant. Twenty-six consonant-vowel (CV) contrasts were selected and each was presented in four permutations: $C_1V_1 : C_2V_2$; $C_2V_1 : C_1V_1$; $C_1V_1 : C_1V_1$; and $C_2V_2 : C_2V_2$. The list of 104 contrast pairs was recorded in random order by a linguist and presented for one-half hour daily, on five days, to individual subjects for judgments of same or different. Incorrect responses were followed by a flash of light. A contrastive analysis of English and Russian and some pilot studies suggested that certain contrast pairs would prove easier to discriminate than others; these were presented to one group of twenty subjects while those considered difficult were presented to another group of twenty.

The first group showed a drop in errors over the five days from 11 to 2 per cent, the second from 22 to 10 percent. The low initial error rates (high base-lines of discrimination) probably reflect transfer of first-language discriminations, discussed above. Based on the error distributions obtained in this experiment, the authors present a rank ordering of the Russian consonants and vowels with respect to difficulty in discrimination learning for English-speaking subjects; the order accords well with that predicted from a contrastive analysis of the two languages.

In a subsequent study, Suppes, Crothers, and Weir (1962) examined discrimination learning among Russian vowel phonemes and the effect of sequencing stimulus presentations according to expected difficulty. The subject was presented with a recorded series of sets of five stimuli during six daily 15-minute sessions distributed over a period of 11 days. Each stimulus was a Russian word containing one vowel preceeded and/or followed by a consonant. The subject was instructed to select the alternate stimulus in each set which contained the same vowel as the first stimulus in the set; he was then told the correct answer. One group of subjects (N = 44) received a fixed series of items in random order (R), a second (N = 54) received progressively longer and more difficult items in each daily session (P).

Figure 5 shows the proportion of errors on each experimental day for the subjects in each group. On day 1, the programmed subgroups naturally show fewer errors since they were presented with only the easier discriminations in the fixed series presented to group R. On days 5 and 6, when both groups were presented the same discrimination series, the programmed group committed a reliably greater number of errors. In interpreting this finding it must be remembered that the programmed group had less training on certain of the difficult discriminations because of the sequencing of stimuli presented to them. The procedure of vowel-phoneme matching from a set of alternatives permits the preparation of a confusion matrix which can serve as a guide to sequencing and repetition in programming the acquisition of the relevant discriminations (cf. Sapon and Carroll, 1958, and discussion below).

These three studies and others (Pimsleur, 1963; Lane & Moore, 1962; Lane, 1962a) illustrate the extensive transfer of first-language discriminations in second-language learning, whether the task be identification, detection of a difference, or recognition, respectively (see Gallanter, 1962). The second experiment by Suppes et al. and that by Swets et al. to be described show, however, that rapid and relatively error-free discrimination learning cannot be assured solely

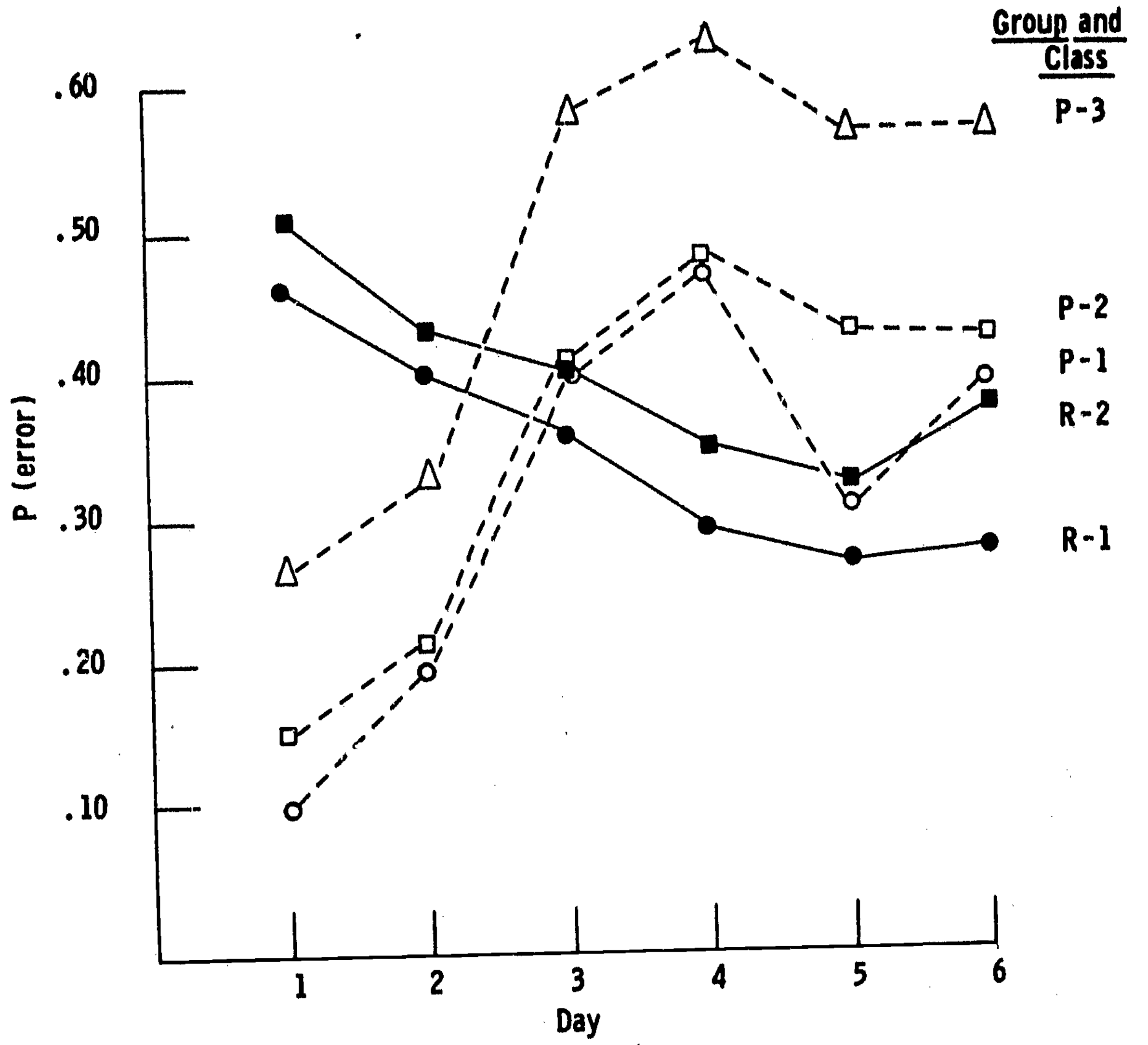

Figure 5. Proportion of errors on each day of discrimination training with Russian vowel phonemes. One group of 44 subjects ("R") received a fixed set of items in random order; a second group of 54 subjects ("P") received progressively longer and more difficult items. (From Suppes, Crothers, and Weir, 1962.)

on the basis of an *a priori* sequencing of item difficulty. Among other requirements, there must be an iterative process of program revision, including the revision, addition and deletion of frames and sequences, based on an analysis of student errors.

Swets and co-workers (1962) applied computer-based programmed instruction to examine the usefulness of overt response, immediate reinforcement, adaptive sequencing, and self-pacing in learning to identify multidimensional sounds. They found that these procedures "produced results that are comparable to those obtained previously with conventional training methods. Certain of the central features of automated instruction were found to hinder learning in the task studied" (p. 928). A description of one of their series of four experiments will illustrate method and results. While seated in front of a typewriter connected to a computer, the subject was presented with one of a set of 32 stimuli over a pair of earphones. Each sound assumed one of two possible values along five dimensions: frequency, amplitude, interruption rate, duty cycle, and duration. Figure 6 shows the percent correct attained on an identification test after a one-hour training session with one of five procedures. In condition 1, at the subject's command the computer typed a five digit number that specified the stimulus and then played the sound; the subject did not emit an overt identification response but proceeded to give the next command. In condition 2, the subject initiated the presentation of the stimulus, then typed the five digit number he believed to identify the sound; the computer typed OK or WRONG and, if wrong, typed

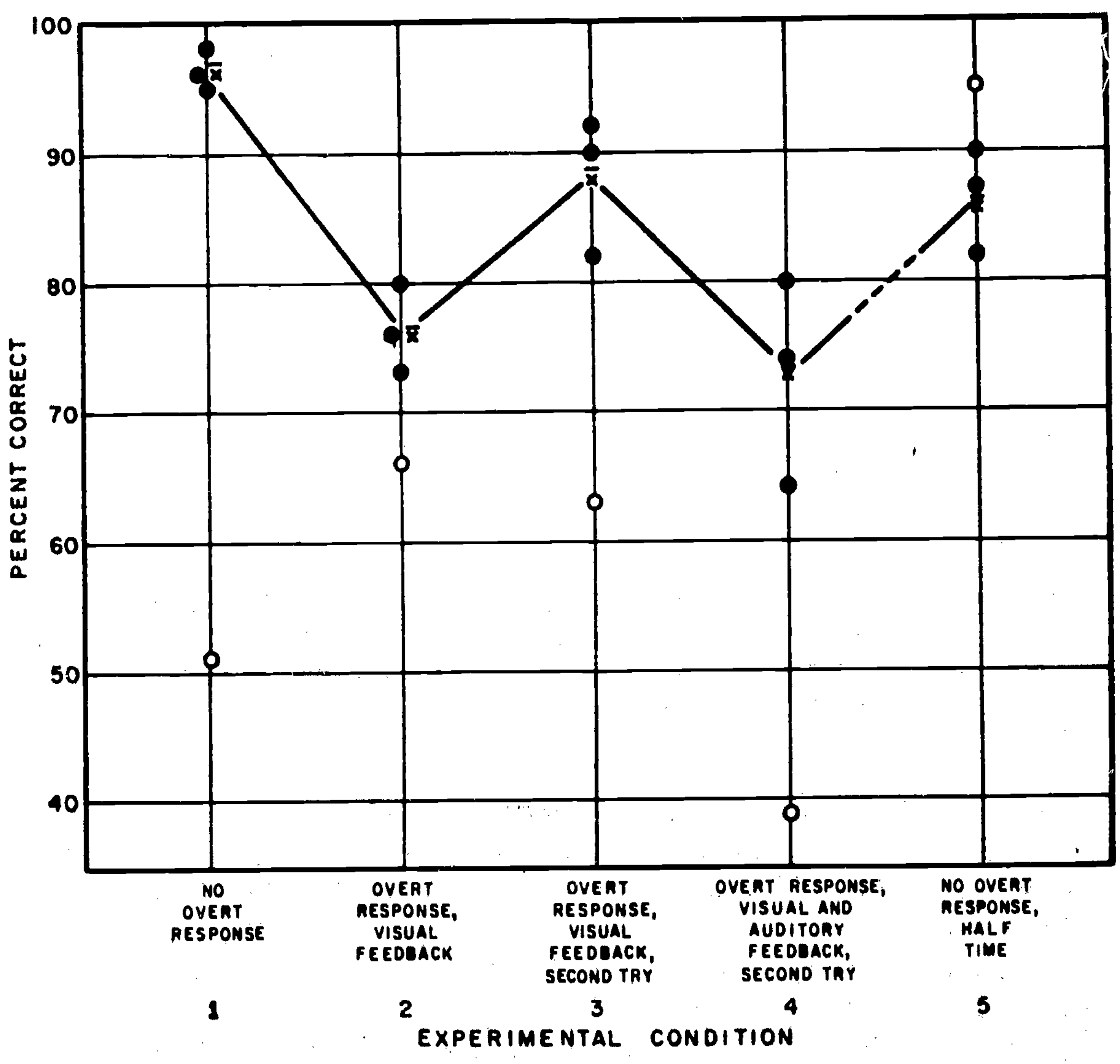

Figure 6. Learning to identify multidimensional nonverbal sounds with a computer-based program. The effects of two types of response, two types of feedback, conditional and unconditional selection of successive items, and three levels of reinforcement probability, on percentage of correct identification. (From Swets *et al.,* 1962.)

the correct answer. Condition 3 was like condition 2 except that, after an erroneous response, the subject received the sound again and made a second attempt at correct identification. Condition 4 was like 3 except that, if the subject gave an incorrect answer, he heard the sound corresponding to it, as well as a repetition of the test sound before he made a second try. In condition 5, the number of trials under the condition 1 procedure was reduced by half so that an equal number of trials was received under all procedures. As a consequence of these procedures the probability of response confirmation varied from 0 under condition 1 to maximal under condition 4. The authors conclude:

> "The data provide no support for the hypothesis that continual interrogation and overt responses are beneficial to learning; [they] show that a fairly extensive feedback may be detrimental ... and provide no support for the hypothesis that efficiency of learning varies directly with the probability of reinforcement" (p. 929).

The authors' conclusions must be generalized with caution. Negative findings in an evaluation of programmed instruction may be attributed to many sources. In second-language learning, these include faulty analysis of the terminal behaviors, false assumptions about the relevance of the experimental tasks to language behavior, and failure to revise the program iteratively, based on an analysis of student errors. Negative findings can be interpreted properly only when they are based on a program that has been shown, under other controlled conditions, to be effective.

The use of auditory stimuli which are synthesized electronically, as in the preceding experiment, rather than speech stimuli uttered by an informant, often provides findings that are more systematic, sensitive, and stable – but at a loss in immediate relevance to the applied problem of second-language learning. Recent advances in speech synthesis (Cooper, Liberman and Borst, 1951; Lawrence, 1953; Fant, 1958) make it increasingly possible to perform comparably well-controlled experiments in programmed learning with speech stimuli; regrettably, these devices have not found application in this area as yet.

Stimulus Generalization

Stimulus generalization, that is, the degree of invariance in responding under changes in stimulus conditions, has received extensive study in the laboratory with both non-speech and speech stimuli. [3])

An experiment by Cross and Lane (1962), employing stimuli varying along a single dimension (intensity of a 500-cps tone), is of particular interest because two incompatible responses were conditioned to two disparate stimuli and then the probability of emission of each response to intermediate stimulus intensities was determined. This paradigm for discrimination learning and generalization testing bears some resemblance to the language-learning situation in which

[3]) For example, see the review by Mednick and Freedman (1960) and studies reported in Mostofsky (1963).

responses from the student's first- and second-language repertoires compete for emission. Figure 7 shows that response probability is maximal and latency minimal when the stimulus associated with reinforcement (S^{D}_1 or S^{D}_2) is presented. When the probabilities of emission of the responses are equal, at a median stimulus loudness, the latency of responding is greatest. Curiously enough, the same findings were obtained when two compatible responses were employed

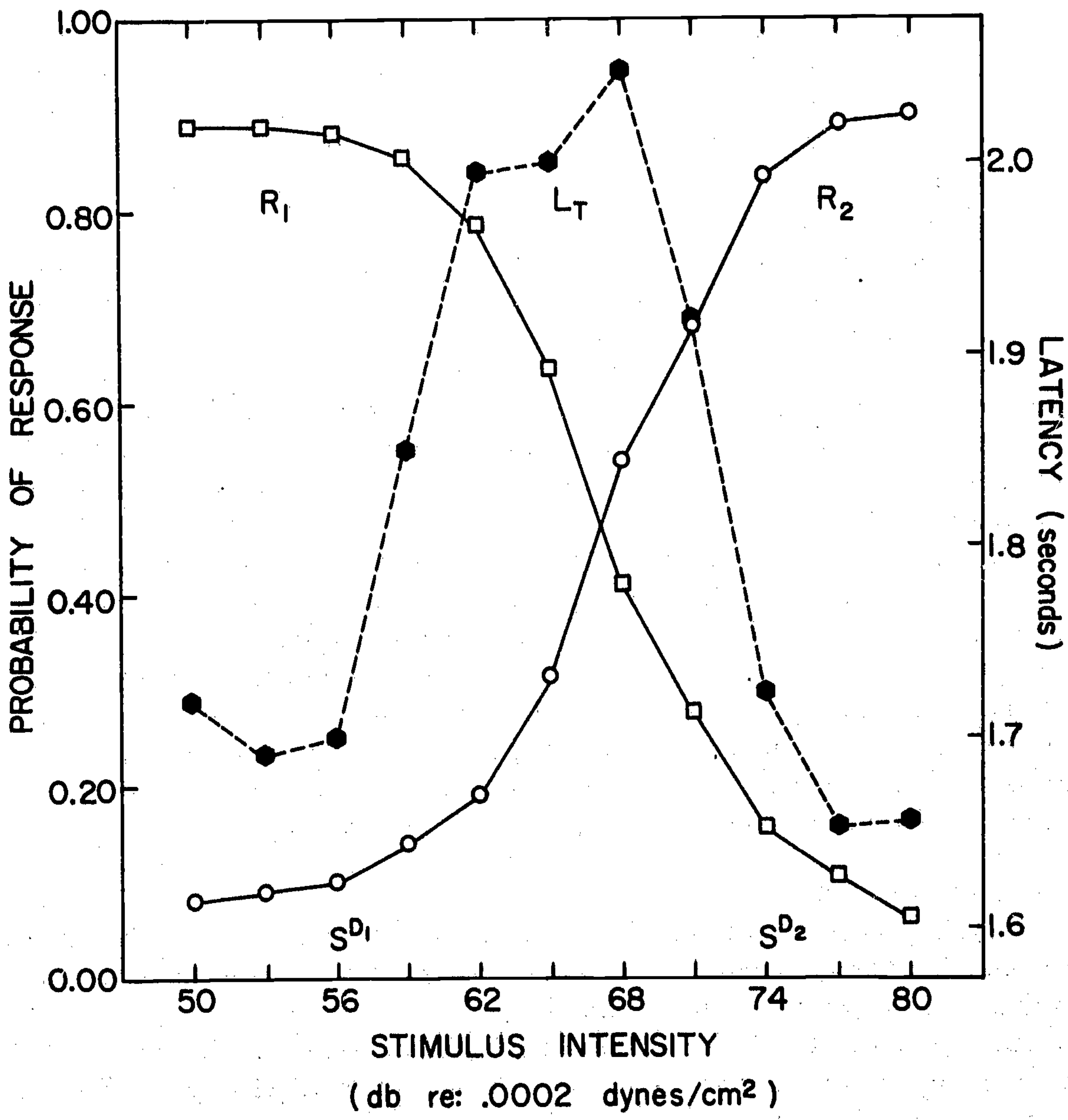

Figure 7. Generalization gradients for pure tone intensity. The conditional probabilities were estimated from the total number of /ka/ responses (R_1) and /ti/ responses (R_2) emitted in ten presentations of each stimulus intensity to each of 20 subjects. The total latency (hexagons) at each intensity is the unweighted mean of the average latency of responding by each of 20 subjects. (From Cross and Lane, 1962.)

(low-pitch vowel and high-pitch vowel); when response probabilities were equal, latency was maximal and there was no evidence of response "blending," i.e., intermediate pitch, under these conditions.*

This experimental paradigm has recently been extended to multidimensional synthetic stimuli with essentially the same results (Cross, 1963). It turns out that, if a discriminative response is conditioned to a stimulus with the properties (a_i, b_i), the degree of generalization to another stimulus, differing along both dimensions, (a_j, b_j), is equal to the degree of generalization due to the change in *a*, $(a_j - a_i)$, plus the degree of generalization due to the change in *b*, $(b_j - b_i)$. It would be interesting to explore generalization in the two-dimensional stimulus array defined by the first- and second-formant frequencies of synthetic vowels. Departures from this simple additive rule of generalization might occur in the region of points which define vowels in the subject's native language.*

Over the past two decades, investigators at the Haskins Laboratories have greatly enhanced our understanding of the perception of speech by measuring the stimulus generalization of listeners responding to synthetic speech stimuli. Illustrative of a segment of this research is a study by Liberman et al. (1961 a) of the perception of the voiced stops /d/ and /t/. Spectrographic patterns were prepared and converted to sound by means of a device called Pattern Playback. The patterns were identical except for the relative onset times of their first and second formants: the first formant was cut back in 10-msec steps from 0 to 60 msec. They were presented in random order to subjects with instructions to label each stimulus as either /do/ or /to/. Cross and Lane (1962) replicated this study with six subjects, and also measured response latency; their findings

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*[Editor's note] The term "latency" refers to the delay between the presentation of a stimulus and the appearance of a response. It is one of the basic measures used to specify a conditioned or instrumental response.

"Generalization gradients" here refer to the regular change in the conditional probabilities, or likelihood, of one or the other response as the test stimulus takes on various intensity values intermediate to the intensity levels of the two stimuli that the experimental subjects had been trained to discriminate between.

*[Editor's note] When subjected to frenquency analysis, all vowels show formant bands, or points of resonance. The first and second formants correspond to the resonant frequencies of the two chambers into which the tongue divides the resonance tube cavity defined at one and by the pharynx, at the other by the lips. With a few exceptions, these first two formant frequencies suffice to specify a particular vowel, that is, to distinguish it from the other vowel phonemes of a given language. Professor Lane proposes an experiment using artificial vowels created by systematically varying the first and second-formant frequencies; and he suggests that as the two frequencies approached those values characterizing a vowel of the subject's native language, there might be a discontinuity in the nature of his response: he might distinguish the stimulus with these values from all the others, which are non-linguistic, more often than he distinguishes among the non-linguistic stimuli themselves.

are shown in Fig. 8. Since the /do/ and /to/ response-gradients are complementary, only the former is presented. The reader may wish to compare these data with those in Fig. 7; both experiments measure stimulus generalization after two incompatible responses have been conditioned to two discriminative stimuli. In studies of generalization among first-language speech stimuli, prior discrimination training has been arranged, of course, by the verbal community and is not controlled by the experimenter.

The average generalization gradient in Fig. 8 is more shallow than that for individual subjects. A very steep phoneme labelling gradient (in the extreme case, a step function) means that the subject responds alike (generalizes) to all stimuli within a phoneme class and discriminates completely between stimuli drawn from the separate classes.* In other words, discrimination training has effectively partitioned the stimulus *continuum* into two discrete classes of stimuli: /do/-

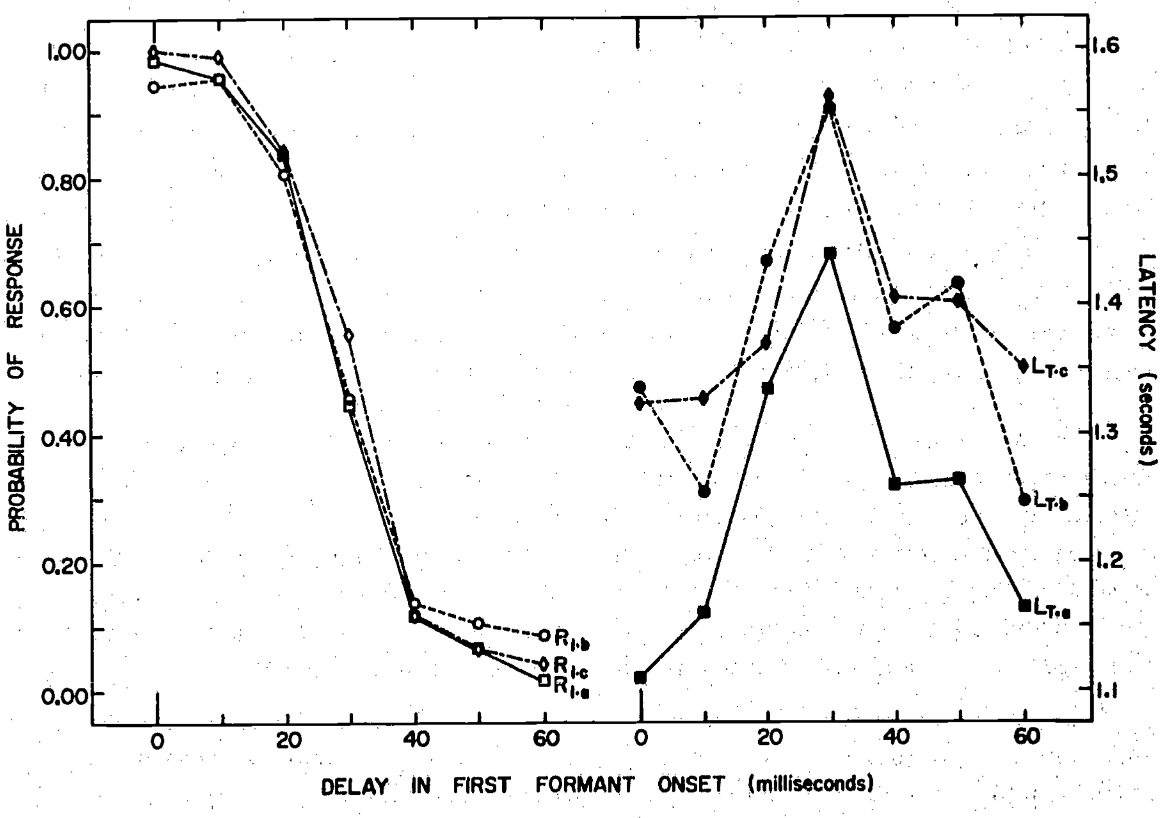

Figure 8. Generalization gradients for synthetic speech stimuli, ranging from /do/ to /to/. The conditional probability and average latency of a labelling response in ten presentations of each stimulus to each of six subjetcts. The functions labelled (a), (b) and (c) were obtained under instructions to label the stimuli as /do/ – /to/, /to/ – /do/, and /ka/ – /ti/, respectively. (From Cross and Lane, 1962.)

*[Editor's note] A step function means a curve with a 90 slope, in the present case one that at one point on the scale plunges from a very high response probability to a very low one.

stimuli and /to/-stimuli; that is, into two phoneme categories. Support for this conclusion comes from further experiments by Liberman and his co-workers with a number of phonemic contrasts. They find that a subject has great difficulty in distinguishing (in a psychophysical task) between those stimuli which he labels alike, i.e., those drawn from the same phoneme category, while he readily discriminates stimuli drawn from different phoneme categories. Particularly noteworthy is their finding that discriminability of the two phonemes is predictable from the labelling gradients. The analogous finding for a non-speech continuum such as pitch would be that the listener discriminates only as many pitches as he can name. This conclusion is in error by a factor of about 200 (the number of DL's for frequency at moderate intensity divided by the magic number 7).*

Liberman (1957) argues that, in the case of speech stimuli, the physical continuum is broken into two discrete perceptual classes because two discrete responses mediate between the stimulus presentations and the recognition (labelling) or discrimination (same-different) responses. Thus, for the acoustic continuum in Fig. 8, stimuli differing in the delay of first-formant onset evoke covertly either the /do/ response or the /to/ response; these discretely different covert responses (voiced-voiceless) — or their neural correlates — then control the overt discriminations by the subject. This account of speech discrimination in terms of response differentiation, called the motor theory of speech perception (Lisker, Cooper, and Liberman, 1962), has important implications for selecting a procedure by which these two components of formal repertories shall be conditioned and coordinated (see below).*

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*[Editor's note] DL's are difference limens and stand for the just noticeable differences that can be detected in a sensory continuum. Within a frequency range of 31 to 11,700 cycles, about 1400 tones can on an average be distinguished on the basis of relative judgment (same-different). However, if an average untrained subject is called upon to make an absolute identification of different tones, in other words to label or name different tones (A, B, C, etc.), it makes little difference how many different tones are presented to him for identification: he will class them into about seven pigeonholes and make his identification on the basis of these categories, which he freely rearranges "... along the pitch continuum to accommodate almost any distribution of stimuli" (F. Attneave. *Applications of Information Theory to Psychology.* NY 1959 p. 69). Cf. also G. A. Miller. "The magical number seven plus or minus two: some limits on our capacity for processing information". *Psychol. Rev.* 1956, 63, 81–97.

*[Editor's note] A mediate response is one, not necessarily available for inspection, that intervenes upon a given stimulus and itself serves as the stimulus for the observed response. In the present discussion, the mediate response is a covert neural or neuro-muscular response associated with the articulation of the syllable [do] or [to]. The labelling or discrimination response is made not to the original stimulus, but to the covert one.

The experiments in stimulus generalization described above sampled the formal repertoire called dictation since non-vocal responses were under the control of an array of auditory stimuli. Since only two responses were employed in each of the studies, an extensive, differentiated repertoire of responses was not required. A number of experiments on generalization among speech stimuli that differ along several dimensions have capitalized on the extensive repertoire of vocal and written responses that is the largesse of first-language learning. With this technique, a confusion matrix* may be obtained: the discrete stimuli are the column headings, the discrete responses the row headings, and the frequency of occurrence of R_i over the *n* presentations of S_i gives the entry in the i^{th} cell. Thus, a confusion matrix is a set of generalization gradients where, typically, the independent and dependent variables are nominally scaled (*vide* Stevens, 1951).*

A study by Sapon and Carroll (1958), who determined confusion matrices for selected words from English, French, Spanish, Portugese, Italian, and

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*[Editor's note] A confusion matrix is a tabular arrangement of experimental matching or identification data that facilitates the systematic confrontation and analysis of a large number of variables.

If we imagine an experiment where 100 subjects are called upon to identify a set of four phonemes, /f/ /v/ /θ/ /ð/ , certain of which, for example, were absent from the subjects' native language, the outcome might take the form of the following matrix (the figures are quite imaginary):

STIMULUS

RESPONSE		/f/	/v/	/θ/	/ð/
	/f/	55	15	18	3
	/v/	20	60	10	12
	/θ/	20	10	52	23
	/ð/	5	15	20	62

Sample confusion matrix . N = 100

This simple matrix assembles a considerable amount of data. If the experiment included additional phonemes such as /s/ /ʃ/ /z/ and /ʒ/ , then the task of organizing and using the resultant data would be quite formidable without the help of such a matrix.

*[Editor's note] "The *nominal scale* represents the most unrestricted assignment of numerals. The numerals are used only as labels or type numbers, and words or letters would serve as well." (Stevens, *loc. cit.)*

Russian, illustrates this type of experiment. The procedure was similar to that later employed by Suppes, Crothers, and Weir (1962), described above. Japanese, American, and Latin-American listeners with virtually no second-language training were employed. The pattern of errors in phoneme matching was found to be nonrandom; significant differences among the three language groups of listeners were obtained. To cite one example, stop consonants were always matched with other stop consonants by Latin-American listeners, while American and Japanese subjects often chose fricatives. In the light of these findings, the authors properly warn against interpreting confusion data obtained with one language group as generally characteristic of human sensory processes or stimulus generalization.

As indicated earlier, these confusion matrices provide a valuable guide to the second-language programmer and an empirical check on the order of discrimination difficulty based on contrastive analysis. Reiff (1961) has suggested that this analysis would ideally contrast each student's idiolect with that of the target language. Short of this extreme, he mentions that the Linguistic Atlas of the United States may serve as a guide when the student's residence is known. For example, "a native of Eastern Pennsylvania will need a heavier preponderance of the discrimination [ó] [ə́w] — or [éw] — than between [ó] and [ów]" (p. 91). It does not seem implausible that programs to condition second-language echoic behavior which are developed in different regions of the United States may differ in their emphasis on certain discriminations.

Response differentiation

The differentiation of spoken or written responding, which is the second requirement of a formal repertoire, is predicated on the inherent variability of all behavior. In the laboratory, the technique of shaping or response differentation amounts to this: "We select one (or more) of the 'natural' variations of a well-conditioned response and give it *exclusive* reinforcement; the remaining variations are subjected to *extinction*. If we pickout, in advance, a variation that has been of fairly frequent occurrence, and if we apply this selective reinforcement rigorously, we can soon produce an increase in the frequency of the response that possesses the property or properties that we have chosen" (Keller and Schoenfeld, 1950, p. 186).

Differential reinforcement of vocal responding has rarely been studied in the laboratory; this is particularly regrettable in view of its importance in the acquisition of second-language fluency and the relative ease with which the topography of this behavior may be measured (*vide* Lane and Shinkman, 1963). A study of shaping vocal duration, reported by Lane (1964 a), illustrates the method and findings in this application. The subject is seated in an audiometric room in front of a microphone, light, and coin dispenser. He is told to say /u/ when the light flashes and that the only pay he will receive will be dispensed in front of him, contingent on appropriate behavior. Each of the first 20 responses receives reinforcement (1 cent) and its duration is noted. A subclass of this operant is then chosen for selective reinforcement. In the experiment whose findings are shown in Fig. 9 the mean (M) and average deviation (AD) of the set of 20 responses was computed and, in the second phase of the experiment, all responses whose duration exceeded $M_1 + AD_1$ were reinforced. The phase was continued until 10 successive reinforcements were received. Then, $M_2 + AD_2$ was computed for these 10 responses, and this value set as criterion for phase 3. In this fashion, the vocal duration of the subject was shaped (filled triangles) from approximately one-fifth of a second to nearly one-half second. After the fifth phase, the experimenter reversed the direction of shaping, now reinforcing all responses with duration less than $M_5 - AD_5$. The experiment was terminated when the subject's vocal duration was reduced to one-tenth second. This subject,

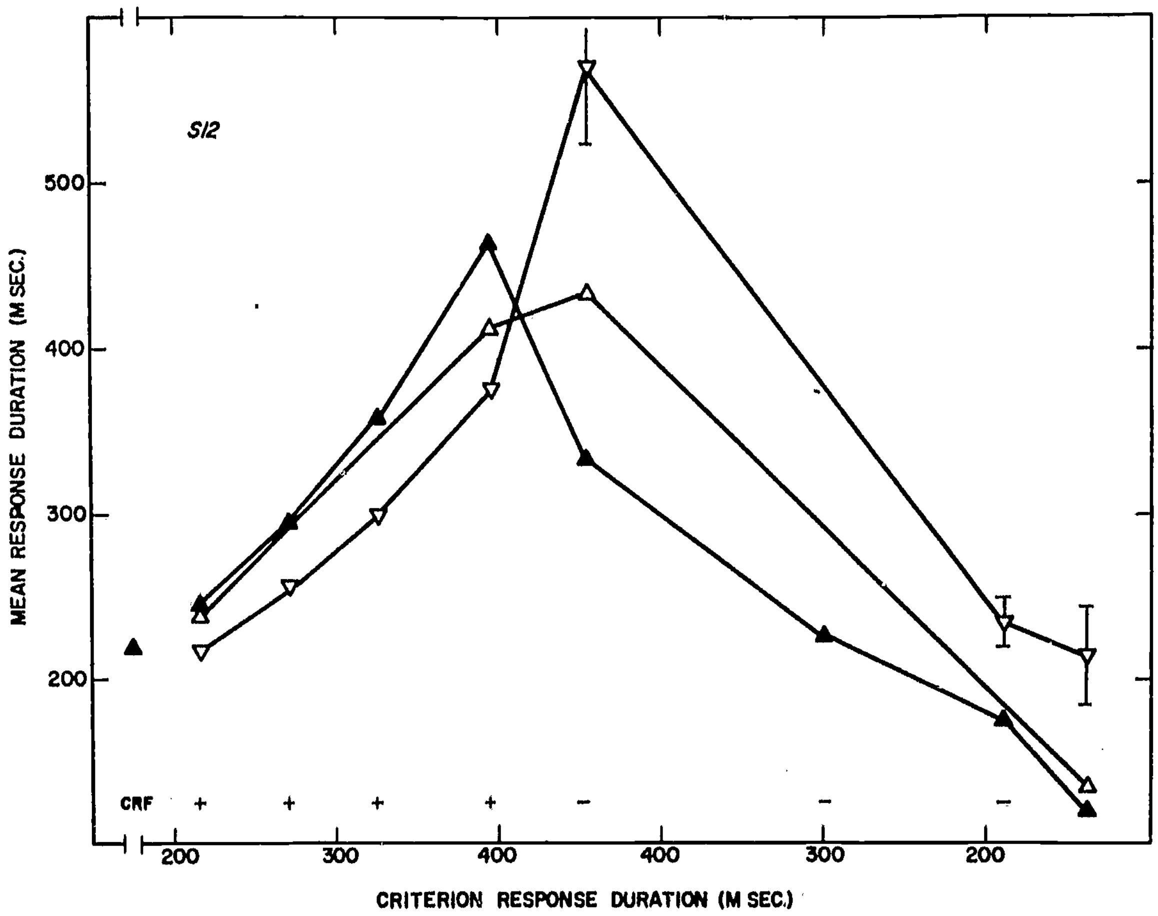

Figure 9. Differential reinforcement of vocal duration with one subject; shaping longer and then shorter durations. The relation between criterion response duration for differential reinforcement and the mean duration of unreinforced responses (inverted triangles), non-terminal reinforced responses (open triangles) and the ten terminal reinforced responses (filled triangles) in each phase. (The pluses indicate the reinforcement criterion for each successive phase during the shaping of longer durations; the minuses indicate the criteria during the shaping of shorter durations.) (From Lane, 1964 a.)

like most of the others whose behavior was similarly manipulated, was unable to report the property of his behavior that produced the money ("unable" in the sense that extensive prompting by a carefully-worded questionnaire, presented after the experiment, failed to yield an accurate report, if any at all).

Other experiments in this series varied the "size of step" that the subject had to take from one phase to the next; that is, the difference between the mean duration of ongoing responding and the new criterion, (C−M), was varied. A significant generalization arose from the data for over 30 subjects and a wide variety of step sizes. It was not possible to predict, from the size of step alone, either the success of the shaping process, that is, whether the subject would reach criterion, or the amount of shaping necessary before criterion was reached. However, it was possible to predict the length and outcome of the shaping process when the step size (C−M) was expressed in terms of the variability (σ) of ongoing behavior. The statistic $\frac{C-M}{\sigma}$, called the shaping index, was correlated 0.4 with the number of responses that were emitted before criterion was reached, and it was found to be large whenever the shaping process failed.

When the shaping index is large, either because the step size is large, the variability small, or both, the *a priori* probability of a reinforced response is low and the success of the shaping process is endangered. When the shaping index is small, the probability of a reinforced response is high and the success of shaping is secured; however, this may require many small steps to lead from the student's initial repertoire to the desired terminal repertoire. Therefore, the security of the shaping process and its efficiency are maximized when the probability of a reinforced response is set at some value, as yet unexplored, between zero and one, through a suitable choice of step size. It may not be too great an extrapolation of the initial findings of this research to suggest that the widely-discussed issue of step size in programming various subject matters should be viewed in this light: the optimal size of a step is best defined in terms of the behavior of the individual student just before taking that step, so that the probability of a correct responce has some constant, intermediate value (cf. Geis, 1961).

The technique illustrated by these experiments in shaping response topography should provide a basis for measuring the interference produced by the first-language repertoire during shaping of second-language fluency. Just as the predictions of difficulty in discrimination-learning provided by a contrastive analysis may be verified by studies of stimulus generalization, so too these predictions for difficulty in response-differentiation may be verified by measurement of response topography during experiments in shaping.

An article by R. J. Sweet (1961) describes the application of contrastive analysis to the prediction of difficulty in response shaping, with particular relevance to sources of interference between English and French repertoires. "The control of pronunciation, then, involves the sequencing of phonemic elements and their combinations so as to minimize the possibility of confusing phonemes and their combinations in the new language with others already acquired in the native tongue. Sequencing of these elements depends upon the existence of varying degrees of difficulty in their pronunication" (p. 56). The author reports that pupils in his classroom research most often mispronounce those French words which are nearly approximated in English; e. g., *papier* and paper, *brosse* and brush, *personne* and person.

Several writers, among them Sweet (1962) and Hayes et al. (1962), have suggested that the shaping of new response topographies may be accelerated by employing those in the first-language repertoire. For example, the student may be led to a correct pronunciation of the German *ich* via the following steps: (1) "fish," (2) "fish" said through spread lips; (3) "fish" said through spread lips while opening the teeth slowly (after Hayes et al., 1962). The danger of such techniques is, of course, that they evoke the very responses in the first language which are sources of interference and must be weakened. Here the language programmer faces a choice, unguided as yet by research findings, which recurs in programming other repertoires as well (see discussion of *textual behavior* below). By calling into play first-language discriminations and patterns of responding, an *approximation* to the desired terminal behavior is more quickly attained, but it may then be more difficult to move precisely onto target.

Coordinating discrimination and differentiation

In any formal repertoire, there is a point-to-point correspondence between stimulus and response, whether these be spoken or written. The second-language programmer must undertake, after engineering discrimination and differentiation separately, to coordinate them. The mastery of International Morse Code illustrates the paradigm; there are 36 basic stimulus patterns each connected with a differentiated response pattern. "When one learns to *receive* code, his problem is mainly *discriminative,* since the written or spoken responses have already been well-differentiated; in *sending* code, however, the problem is one of differentiation, since the discriminative work was done when the student learned to read his ABC's" (Keller and Schoenfeld, 1950, p. 193). Note that conditioning a formal repertoire, such as receiving or sending code, establishes a minimal functional unit of behavior and permits the appropriate extension of this repertoire to new cases. The "minimal textual repertoire" involved in sending Morse Code, for example, is extended whenever the telegrapher sends words from English text which he has never seen before.

A consideration of the development of echoic behavior will illustrate the problems of coordinating discrimination and differentiation in any of the four formal repertoires. We may restrict our attention to strategies for conditioning a minimal echoic repertoire which is later extended to new stimuli as the occasion demands. This minimal repertoire is vital to second-language learning for, once it is conditioned, the programmer can evoke new responses as an assemblage of small echoic units never before arranged in this order; this behavior may then be reinforced.

When programming echoic behavior in a second-language, certain auxiliary behaviors by the student, which are normally taken for granted in other kinds of programming, are not available. In the more common "subject matter" programs, confirmation is contingent upon not only a correct response but also upon a correct discrimination by the student; namely, that his written response "is the same as" the printed answer. This requirement of a discrimination is rarely mentioned and remains unobtrusive until the student erroneously considers equivalent such response-confirmation pairs as, "can not" and "does not" (Holland, 1959). Under these circumstances, an incorrect response is strengthened to the degree that the confirmation stimulus acts as a reinforcer.

The requirement of a discrimination for self-reinforcement obtrudes from the start, however, in programming second-language acquisition, for these discriminations are not part of the initial repertoire of the student. For example, Pimsleur (1963) writes:

> "The popular notion is that the student who is able to compare his pronunciation with that of a native speaker will acquire nativelike speech. Many teachers have already realized that this hope is far too optimistic. It is evident that students are rather poor judges of their own pronunciation. They are prone to think their pronunciation is "good enough" when actually it is not acceptable. They are unable to note which features are relevant and which are not" (p. 199).

In conditioning echoic behavior, the programmer's task is further confounded by the fact that the confirmation stimulus and the subject's response are both fleeting and presented via different modalities; an aural stimulus in the first instance, sidetone and bone conduction in the second. Furthermore, psychophysical differences in the perception of external vs. "autophonic" (self-generated) sounds probably impede the development of accurate echoic behavior (vide Lane, 1962b).

How then shall the student's echoic behavior be selectively reinforced? Assuming that each student shall not have access to a private tutor or to an automatic speech recognizer, there seems to be little choice but to condition the prerequisite discriminations in the first place, and arrange for their maintenance during later conditions of *self-shaping* echoic behavior. There is inadequate laboratory evidence, however, to confirm that the relevant discriminations, once conditioned, are effective in self-shaping echoic behavior, although the pedagogical success of programs predicated on this assumption suggests its validity (vide Morton, 1961a, and the following section).

A series of 11 pilot studies and three major experiments by Pimsleur, Mace, and Keislar (1961) are among the few that examine the effects of discrimination training on response differentiation. The central problem of their research was "to determine the value of preliminary discrimination training in increasing the effectiveness of language laboratory practices on the pronunciation of French sounds." They found: "(1) Training in discriminating the French nasal vowel phonemes /õ/, /ɔ̃/, /ɛ̃/, rendered subsequent language laboratory practice more effective in producing good pronunciation of these phonemes. (2) Training in discriminating between the dipthongized and the undipthongized final /o/ did not render language laboratory practice measurably more effective in producing good pronunciation of this French phoneme" (p. 25). Note that the first discrimination is among phonemes in the target language, while the second is between a French phoneme and a troublesome English approximate. Pimsleur (1963) attributes the different outcomes to the greater degree of response differentiation that existed in the former case for native speakers of English.

A close relation between speech discrimination and differentiation is again implied by the outcome of a programming experiment in speech correction. With a carefully designed and executed program that should serve as a model for others, Holland and Matthews (1963) taught /s/ discriminations to children who misarticulated /s/. The discriminative response was button-press; correct responses simply led to the next item; incorrect responses caused the tape recorder to rewind and repeat the last item. Phase 1 of their program involved discrimination of /s/ in isolation from other isolated speech sounds. The latter were sequenced according to difficulty and faded in toward equal intensity with the S^D. In Phase 2, the subject was required to discriminate the sound in words. Sequencing of difficulty and fading were again employed. For example, words with initial /s/, terminal /s/, and medial /s/ were presented in that order. In Phase 3, the child was asked to identify the position of /s/ within a word. Phase 4 involved discrimination of correctly articulated from misarticulated /s/ sounds within words; omission, substitution, and distortion comprised the misarticulations.

The group of children who worked through this program showed significantly improved /s/ discrimination, sibilant discrimination, and, of particular interest here, improved /s/ *articulation* on a series of tests.

There are several considerations, however, that strongly question the value of discrimination training before response differentiation. The first of these is the outcome of an experiment by Lane and Schneider (1963) that measured the accuracy of self-shaping echoic responding to Thai tonemes under several procedures. These authors report that discrimination training, in which the target toneme was contrasted with segments of the same form but different durations and pitch slopes, did not lead to a marked improvement in echoic accuracy. The further introduction of delayed auditory feedback of the subject's response, facilitating comparison of the model and his attempt at imitation, also failed to produce an appreciable improvement in the correspondence of stimulus and response pitch or duration. The juxtaposition of model and imitation did not lead to an improvement in echoic accurracy despite the fact that the subjects had previously shown perfect discrimination between tonemes that were more similar than the model and their attempts at imitating it. This high level of discrimination was reached rapidly during training and probably reflected transfer of first-language discriminations, as discussed earlier in this article in the section on *Discrimination.* The findings reported in that section, taken together with these data on echoic behavior, indicate that inadequate response-differentiation can persist despite a very fine-grained discriminative repertoire.

Research at the Haskins Laboratories on the generalization of synthetic speech stimuli, discussed earlier, casts further doubt on the necessity of discrimination preceding differentiation in the conditioning of formal repertoires. Indeed, inference from these findings suggests that discrimination training ideally should follow response differentiation. In a review of research on speech perception, Liberman (1957) writes: "All of this strongly suggests ... that speech is perceived by reference to articulation - that is, that the articulatory movements and their sensory effects mediate between the acoustic stimulus and the event we call perception" (p. 122). It follows from this motor theory of speech perception that two relatively similar external stimuli could be made more discriminable "if we could attach to those stimuli two very different mediating responses and hence gain the added distinctiveness of their very different proprioceptive returns" (p. 123).

As an example of this suggestion we may consider the implications of the studies by Liberman et al. (1961b) on the discrimination of /p/ and /b/ in intervocalic position. An experiment similar to the /do/ – /to/ study described earlier was performed with the synthetic speech stimuli, /ræbɪd/ – /ræpɪd/. These stimuli varied only in the duration of the silent interval between the two syllables in each word, which ranged from 20 to 130 msec. Labelling responses by native Americans "partition" the stimulus continuum into two perceptual classes: /ræbɪd/ stimuli and /ræpɪd/ stimuli. This outcome is attributed to covert mediating responses which provide discrete cues (e.g., voiced-voiceless) for the labelling judgments. A modest extension of Liberman's hypothesis suggests that a foreign student who has not learned the differentiated response patterns /b/ – /p/ in English should find this auditory *discrimination* much more difficult than do native Americans. Moreover, if the new responses /b/ and /p/ are differentiated out of the student's current vocal repertoire, this should enhance the discrimination of /b/ and /p/ when presented to him as auditory patterns, for now the student's responding may be controlled by intervening articulations that provide very different proprioceptive cues.

Further support for the suggestion that vocalization may facilitate the development of speech sound discrimination comes from some observations reported by Holland and Matthews in their study of /s/-discrimination, discussed above. The authors actually compared several programs for conditioning this discriminative behavior; they note that the one described earlier produced the most spontaneous vocalizing by students working through the program as well as the greatest improvement on the /s/-discrimination tests. They suggest that "these vocalizations might force careful observation of auditory cues, or they might provide supplemental kinesthetic stimuli which could be useful in close discriminations."

It is unfortunate that the pedagogical implications of the motor theory of speech perception have not been put to empirical test. The outcome might have importance not only for second-language learning but also for an evaluation of the theory itself, which presently lacks a firm empirical basis (*vide* Lane, 1964c; Cross, Lane and Sheppard, 1964).

Echoic Behavior

Among the four formal repertoires delineated earlier, echoic behavior, involving a spoken response to a spoken stimulus, receives the major emphasis in modern-language pedagogy. "Today we are pretty much in agreement that the grammar-and-translation method, patterned largely on the traditional study of Latin, is obsolete at the least" (Mildenberger, 1962, p. 168). Instead, the major emphasis is on aural presentation of stimuli and oral response-the *audiolingual* method. The objectives of the method include thematic repertoires to be discussed later, but its *modus operandi* involves the purely formal components of an echoic repertoire. "The justification for this emphasis is found in the observation that a language is first of all a system for social communication; writing is a secondary derivative system for the recording of spoken language ..." (Carroll, 1962, p. 5).

The audio-lingual method may be characterized by Brooks' (1959) well-known dicta: "1. The learner should hear only authentic foreign speech. 2. He should hear much more than he speaks. 3. He should speak only on the basis of what he has heard. 4. He should read only what he has spoken. 5. He should write only what he has read. 6. He should analyze, if he does so at all, only what he has heard, spoken, read, written, and learned."

Despite the widespread use of the audio-lingual method and the related proliferation of language laboratories (Hayes, 1963), considerable uncertainty remains about the value of this approach to second-language learning. Questions such as these, posed by K. A. Mueller (1962), are largely unanswered by available research findings: Does withholding texts, and the absence of reading and writing, in the early stages of language learning by this method affect performance in pronunciation, oral comprehension, reading, writing and syntax at various stages in the course?* Does the use of the language laboratory contribute to performance on audio-lingual skills and on others, too? What types of language laboratory facilities are most valuable (vide Morton, 1961b) in producing second-language fluency?

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* [Editor's note] The paper of Sawyer *et al.* "The utility of translation and written texts in the first thirty hours of language study". *IRAL*, 1963, 3–4, 157–192, addresses itself to this question.

Scherer and Wertheimer (1962) sumarize the dispute over the audio-lingual method:

> "Inherent in the assumptions underlying an audio-lingual approach to foreign language learning is that students trained only audio-lingually at the beginning will subsequently reach, and perhaps surpass, in reading and writing ability, students who have been trained in the more conventional manner, while exhibiting a far higher level of achievement in auditory comprehension and speaking; advocates of the traditional multiple approach, with its heavy emphasis on grammar and reading, are of a contrary opinion. Little evidence based on controlled experimentation exists" (p. 298).

These authors have performed a rigorous and comprehensive experiment to contrast the effects of the audio-lingual method, which employs primarily echoic behavior, to those of "traditional" methods, which rely more heavily on textual behavior. Noteworthy among their criteria were several novel tests of "habituated direct association" (roughly, "the ability to think in German"), which are described by Wertheimer and Scherer (1962). To précis their findings: audio-lingual students were superior in listening and speaking ability, comparable in reading and writing, and inferior in translating when compared to a control group taught by traditional methods. The former were also superior in responding to spoken German rapidly, appropriately, and in a fashion comparable with that of German bilinguals. (Other comparisons of traditional and audio-lingual methods are cited by Carroll, 1962.)

The third tenet of the audio-lingual method-the student should speak only on the basis of what he has heard-may be reflected in the decision of many language programmers to condition discrimination before response differentiation. The decision cannot be based presently on laboratory research, for the findings, discussed in the earlier section on Coordination, are equivocal. Sapon (1961a) incorporates the audio-lingual principle in his program in elementary Spanish: "In evaluating any program, one must remember that an individual can say only what he can hear, and one of the great strengths of this program is its training in auditory discrimination" (p. 8). Morton's (1960) audio-lingual program for Spanish also has this approach. His first "hypothesis" and procedure in the program is called "Phonematization":

> "Essentially, this would hold that the incipient language learner learns first to 'hear' and discriminate between all 'significant classes of sounds in the new language before a conscious effort is made to reproduce them; or, indeed before any real capability exists for reproducing them. It is an aural conditioning necessary to set up the 'phonemic areas' which will work finally in his acoustico-neurological system like a series of narrow-band filters, passing appropriate sounds, rejecting others automatically..." (p. 14).

When discrimination learning is accomplished, most second-language programs move on to echoic behavior, in the hope that the prerequisite response-differentiation will literally take care of itself (through some mechanism of self-shaping). For example, in Morton's audio-lingual Spanish program the procedure of "Phonematization" is followed by one called "Sound Reproduction":

"... automatic reproduction of all speech sounds as individual acoustic segments is achieved *after* phonematization of these sounds... By means of the 230 individual sound reproduction drills, the student was expected to learn to render correctly, both in isolation and in combination, all of the sounds and sound groups (syllables and utterances) phonematisized earlier" (p. 16).

Similarly, programs in elementary French by Valdman (1964) and by T. Mueller (1962) begin with discrimination training, followed by response differentiation through echoic behavior. In Mueller's program, each vowel and consonant defines a separate unit in discrimination training. Each unit "teaches the student to discriminate against the S^{Δ} sounds and, after that, against the various intonational features such as: pitch, stress, rhythmn, and syllabification" (p. 1). Selfshaping of echoic behavior follows this discrimination training.

Lermontoff (1961) advocates the early introduction of textual material in programming echoic behavior. He argues that "some subjects find it easier to discriminate two sounds after they have read words in which they occur." Consequently, this author's program in elementary French has the following features:

"We first present a new word aurally; and next we have the subject listen to it again and repeat it; then we have him listen to it and repeat it while he is at the same time presented with its written form; and finally we have him read the word aloud and then let him hear the correct pronunciation on the tape" (p. 75).

A French program by Moraud (1961) also integrates echoic and textual behavior. The conditioning procedure has six steps.

"1. [The students] hear a sentence ... and read the text presented ... unless the text has been faded out completely. 2. They repeat the sentence into the microphone or give answer into microphone. 3. They write answer on answer sheet unless instructions call exclusively for an oral response. 4. They listen to correct oral response and read correct written response. 5. They make appropriate connections. 6. They move to the next frame" (p. 24).

Rocklyn (1961) and his collaborators have prepared programs in several languages to condition echoic behaviors concurrent with a limited thematic repertoire. Their effort is of particular interest because they have applied linguistic and behavioral analysis to the choice of terminal behaviors as well as to the design of a program. Usually, the second-language programmer must accept the target language as given. However, programming should be viewed as one technique among many in educational technology and, whenever it is possible to do so, the entire learning task should come within the purview of the behavioral engineer. A report by Rocklyn and Moren (1962) describes programming technique of this group as applied to the acquisition of a limited tactical language in Russian. The language was designed to include 16 commands (e.g., "hands up"), 10 question frames ("how many"), 100 inserts ("tanks, guns"), and

100 answers (yes, no, numbers, etc.). The conditioning paradigm included a recorded Russian or English stimulus, a student response in either Russian or English, depending on the stage in the program, and a recorded correct utterance as confirmation.

Although the acquisition of echoic behavior overlaps with that of thematic repertoires in most second-language programs, in a few the two repertoires are strictly sequenced. For example, Morton (1960) writes, concerning his Spanish program, "...automatic reproduction of all speech sounds... is achieved... *before* the consistent use of the sounds in meaningful utterances," (p. 16) and Valdman (1962) reports on his program in elementary French: "We begin with a sound discrimination and production sequence followed by grammatical transformations dealing with features comprised exclusively of sounds that the student has been taught to discriminate and differentiate."

To summarize: Echoic behavior receives the greatest emphasis among the formal repertoires, partly because of the widespread acceptance of an audio-lingual approach to language pedagogy in general. Most often, the development of echoic behavior skips from discrimination training to imitation with the intervening steps — response differentiation and coordination — largely omitted. In so doing, the programmer capitalizes initially on the students differentiated first-language repertoire, leaving to the self-shaping process the resolution of phonetic differences between the two languages. Echoic behavior is taught before thematic repertoires in some second-language programs, and concurrent with them in others.

Several specialized devices have been designed to implement programmed acquisition of echoic behavior. Gilpin (1961) has described a system composed of two tape recorders (master and student) and relay circuitry which is operated by the student with a control panel. Fifteen buttons permit control of the two recorders in a variety of ways that provide an extremely flexible arrangement of stimulus and response recording and presentation. Carroll (1963a) has designed and constructed an audio-visual device, shown in Fig. 10. The device has three operational modes. In the "familiarization mode," the student is first presented with instructions, new material and the like; then he is given some task to perform, such as answering a question; then he finds out whether the response he made was correct or not. There is provision for vocal, written, and multiple-choice (button-press) responding. When the student meets a criterion performance in this mode he proceeds to the "learning mode" which omits instructions and provides only questions and confirmation. After criterion is reached in this mode, the student goes on to the "test mode" where only questions are presented.

Lane and Buiten (1964) have implemented a computer-based system to permit programming and selective reinforcement of echoic behavior restricted to the prosodic features of speech. This system extracts the intonation, tempo, and relative amplitude parameters of a recorded stimulus pattern and of the subject s echoic

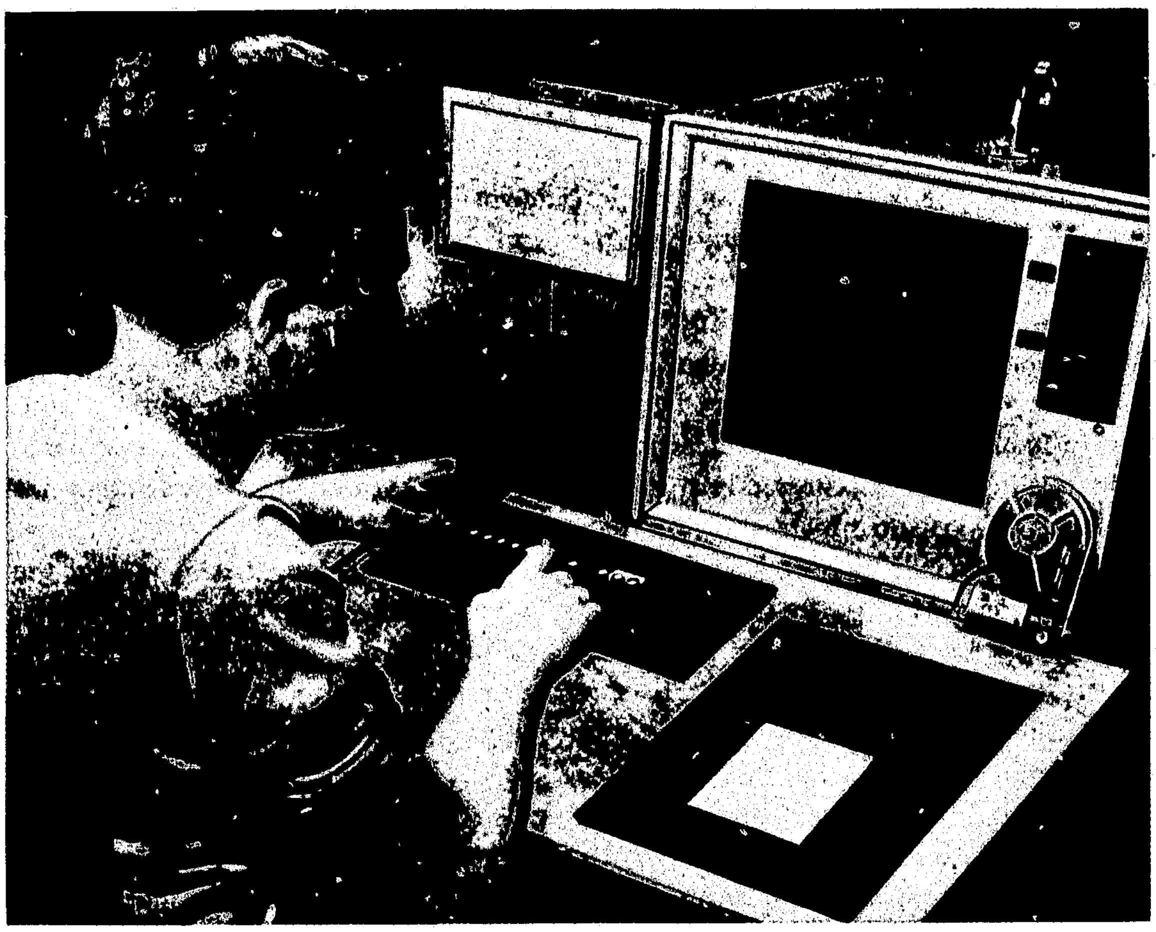

Figure 10. An audio-visual device for self-instruction in language learning. A sample film loop is resting above the projection screen, a sample magnetic tape cartridge along side the screen. To the left of the screen are a loudspeaker and a box containing relay circuitry. In the foreground is the control panel operated by the student and a write-in paper tape. (From Carroll, 1963 a.)

response, compares one or more parameters of the stimulus and response, and presents either an analog or discrete representation of the parameter mismatch to the subject. Depending on the magnitude of the error voltage and a programmable criterion, the subject is automatically presented either with a repeat of the last pattern or with the next pattern in the program.

Porter has surveyed the use of audio-visual aids (1958) and of other instructional devices (1960) in foreign language teaching with emphasis on the implementation of programmed instruction. Carroll (1963) provides a list of teaching machines designed for second-language programs.

Transcription

When both the stimulus and response are written, all the properties of echoic behavior apply in the conditioning and maintenance of transcription. If the second-language orthography is not common to English, the development of a purely formal repertoire will require both discrimination training and response differentiation. Such problems as the minimal unit, extension to new stimuli, coordination and automatic self-reinforcement, which arose in our discussion of echoic behavior, are pertinent to transcription and their solutions are analogous. For example, because the stimulus and the response-product are commensurate in transcription, as they are in echoic behavior, a possible programming strategy is to condition orthographic discriminations and responses initially, and then trust that the student will discriminate the accuracy of his transcriptions, automatically shaping his own behavior to minimize the mismatch between his response and the model pattern. If the second-language orthography is largely the same as in English, the required stimulus discriminations and response differentiation have already been acquired. This is the case for most second language programs. Noteworthy exceptions are the programs that condition transcription in Russian (Saltzman, 1963) and Hebrew (Hammond, 1962).

Textual Behavior

Textual behavior is vocal responding under the control of a non-auditory verbal stimulus. The emphasis here is on the formal properties of such behaviors as reading aloud from a second-language text in that language. Formal and thematic repertoires are combined when a student reads a second-language text while translating into his native language. Many of the problems in programming the acquisition of textual behavior in a second-language are similar to those associated with echoic behavior and transcription discussed earlier. Discriminations within the second-language orthography must be conditioned and vocal responses must, of course, be shaped out of the student's initial repertoire. If the target language employs fundamentally the same orthography as in English, these discriminations require only minimal attention from the programmer. Furthermore, if textual behavior is programmed following echoic behavior, then the requisite response differentiation is available without further conditioning. It remains only to set up correspondences between discriminative stimuli, usually printed text, and differentiated vocal responses.

This strategy in programming corresponds to the fourth tenet of the audio-lingual method — the student should read only what he has spoken — and it has a counterpart in the classroom practice of teaching audio-lingual skills before reading. As Scherer and Wertheimer (1962), K. A. Mueller (1962), and others have pointed out, there is little research evidence in support of this practice. Indeed, when audio-lingual methods have been compared with sight methods in producing speed and retention in reading, all four possible outcomes have been reported: (1) "Oral-aural and reading proficiency constitute separate, independent skills which do not develop one from the other" (Agard and Dunkel, 1948, p. 291); (2) "aural learning facilitates visual relearning, this facilitation is greater than the facilitation of aural relearning by visual learning," (Pimsleur & Bonkowski, 1961, p. 106); (3) "subjects who learned visually and relearned aurally achieved superior performances in comparison with performances of subjects who learned aurally and relearned visually," (Asher, 1962, p. 38); (4) "students taught by the audio-lingual method ... were almost on the same level with students taught by the traditional method in new-type reading and writing tests" (Scherer & Wertheimer, 1962, p. 302).

The greatest difficulty in programming textual behavior arises from a difference between this repertoire and transcription or echoic behavior. The latter repertoires have in common that the response-product and the stimulus occur in the same modality, visual in the first case, auditory in the second. Hence, it is possible to discriminate an improper response by direct comparison with the stimulus. On the other hand, dictation and textual behavior have in common that the stimulus and the response product are dissimilar – they impinge on different modalities. Thus, penmanship can be learned by transcription but not by dictation alone, and pronunciation can be learned from echoic behavior but not solely from textual behavior. Although there is a point-to-point correspondence between stimulus and response in textual behavior, there is no formal similarity between the two which, coupled with speech discriminations, could maintain response differentiation. Skinner (1957) draws the contrast clearly:

> "In echoic behavior, the correspondence upon which reinforcement is based may serve as an automatic conditioned reinforcer. The speaker who is also an accomplished listener 'knows when he has correctly echoed a response and is reinforced thereby. Such reinforcement brings the form of the response closer and closer to the form of the stimulus, the limit being the most precise correspondence possible either with respect to the vocal capacity of the speaker or his capacity to judge similarity ... The automatic reinforcement of reading an 'interesting text, however, has merely the effect of increasing the probability of occurrence of such behavior; it does not differentially reinforce correct forms at the phonetic level" (p. 68).

Although the speaker who is reading text is not able to assess the accuracy of his pronunciation by direct comparison with a model, he is, nonetheless, able to listen to his own speech and this probably has some editing effect on gross mispronunciation. It would be interesting to determine whether the maintenance of response differentiation in textual behavior would be impaired by removing the auditory feedback to the speaker, as through masking of sidetone.* The difficulty of maintaining differentiation in textual behavior need not be a problem for the second-language programmer who desires only to condition "reading a foreign text for understanding." The widespread practice of conditioning students to respond aloud to text in a second language with accurate pronuncia-

* [Editor's note] Sidetone here refers to the spoken sound returning to the speaker's ears. It can be masked by applying a high level of random, "white" noise through earphones to the speaker's ears.

tion, or with the English approximations that the text evokes through generalization with English orthography, seems most inefficient when only translation of text is the goal. Most efficient would be a procedure which brought English vocal responses directly under intraverbal control by the text (see below); no responses in the second language need intervene covertly. A formal repertoire is, of course, sacrificed by this procedure.

Although the acquisition of discriminative control in textual behavior is expedited when the student's first and second languages have largely the same orthography, the maintenance of the differentiative component of textual behavior is hampered by the same tokens. Sapon (1952) advocates the elimination of orthography in the early stages of language learning for this reason. He cites as an example the difficulty of teaching an English student learning Spanish to forsake a lateral continuant in response to the textual stimulus "r" (the product of some years of conditioning) and to emit instead an alveolar vibrant. On the other hand, Lermontoff (1961) was quoted earlier as favoring the introduction of textual stimuli during the conditioning of echoic behavior. The question, unresolved by research, is: does a common orthography in the two languages facilitate the acquisition of textual behavior, by rapidly yielding an approximation to the desired response, more than it impedes this acquisition, by interfering with accurate pronunciation through the evocation of competing responses in the native language.

Sweet (1962) disowns the problem in his Latin program, where response differentiation is of little concern. Programs for languages whose orthography is not common to English, as is the case with the Cyrillic, Hebrew, and Arabic alphabets and Chinese, Japanese, and Korean characters, need not concern themselves with this problem but face another: discriminations among the orthographic symbols must be conditioned. (Saltzman, 1963; Hammond, 1962; Carroll, 1963a).

Dictation

Dictation in a second-language is a formal repertoire that requires the conditioning of speech discriminations as in echoic behavior and, less often, response differentiation as in some cases of transcriptive behavior. The unit of the minimal repertoire may be orthographic, stenographic, phonetic, etc. The lack of formal similarity between stimulus and response is the source of several of the problems encountered in our discussion of textual behavior.

Among the programs that condition dictation, those by Morton (1960) and Harms (1962) bear special mention. Morton conditions dictation as a part of discrimination training; the responses are arbitrary orthographic symbols, called grammalogs; they are transitional behaviors, eventually replaced by differentiated vocal responding during the conditioning of echoic behavior. Harms has developed a program to take a student from no knowledge of phonetic notation to a level of competence whereby he is able to give the phonetic notation at 95 percent accuracy for words selected at random from the Kenyon-Knott dictionary. The program proceeds from dictation of simple sounds through dipthongs and affricates, voiced-voiceless oppositions, stop-nasal oppositions, vowels in CVC frames, consonants with common places of articulation, semivowels, voiced and voiceless consonants, stress, and randomly selected units. The procedure is as follows: the student hears the word on tape, consults a corresponding card for prompting, writes the phonetic notation for the entire word, checks his response against confirmation on the back of the card, and repeats the sequence. Harms presents evaluation data for native and foreignborn students who worked through the program.

THEMATIC REPERTOIRES

Purely *formal* repertoires are of little functional value in their own right either for the speaker (or writer) or his audience. [4]) By virtue of the point-to-point correspondence between stimulus and response that characterizes these repertoires, the behavior is highly predictable and, in that sense, conveys little information. It is only when formal and thematic sources of strength combine in determining a response that we say it is meaningful. Because it has the proper form the response is, first of all, "intelligible"; that is, it has a form appropriate to the discriminative training of the audience. Because the response is also under the control of environmental conditions, or operations on the speaker, or his own prior veral behavior, or that of other people, or several of these acting concurrently, it "tells the audience about" these controlling variables and is likely to be reinforced.

In formal repertoires there is a point-to-point correspondence between stimulus and response – within one dimensional system for echoic and transcriptive behaviors, across two such systems for textual behavior and for dictation. In thematic repertoires, the response shows no such correspondence to the controlling variables. [5]) The term thematic repertoires will be used broadly here to encompass several functional classes of verbal behavior including *intraverbal* responses, which are under the control of prior verbal behavior, *tacts*, which are under the control of nonverbal environmental stimuli, and *mands*, which are

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[4]) Apologies to my secretary.

[5]) Additional contrasts, cited earlier, are the minimal units and their extension to new stimuli that characterize the formal but not the thematic repertoires. We may now qualify this distinction and note that thematic repertoires partake of both properties to a limited degree. Bound morphemes often approximate minimal thematic units. Extension to new stimuli is feasible for sets such as: concur, recur, incur, etc. Larger thematic units may also be extended; the student who knows the meaning of "elephant" has some notion, however crude, of the meaning of "elephantiasis," and so forth.

under the control of characteristic reinforcing consequences (*vide* Skinner, 1957).

Although it is useful to distinguish the controlling relations involved in intraverbals, tacts, and mands, it is important to note that most verbal responses are multiply-determined by several sets of variables acting in concert. For example, the response "fire" may be a tact under the control of a conflagration in one's apartment, or it may be a mand for a characteristic reinforcer ("somebody sound the alarm!"), but it is probably both. It should also be noted that the same "word" may appear in one or more functional classes (in addition to a mand or a tact, "fire" could be an intraverbal response to "Ready, aim, ...").

Intraverbal Responses

Intraverbal relations *within* one language include response patterns variously called syntactic frames or sequences, grammatical structures, redundant strings, contextual constraints, etc. Skinner (1957) treats these under the special heading "autoclitics" in a functional analysis of verbal behavior. Grammatical models, among them Markovian, immediate constituent and transformational, describe this patterning by different analytical techniques. Although these models are of interest to the second-language programmer, especially insofar as they describe the terminal repertoire that the program is designed to produce, a functional analysis of intraverbal chains is of pre-eminent importance since the programmer's task is primarily manipulative.

Unfortunately, there is a great dearth of laboratory research on the analysis and control of intraverbal chaining. Classic studies by Miller and Selfridge (1953) and Miller (1958) describe the potent effects of patterning in recall; recent psycholinguistic studies by Berko (1958), Brown and Berko (1960) and Brown and Fraser (1962) describe this patterning in the language of children; Miller (1962) reports several experiments on the effects of patterning on speech perception; techniques for conditioning and maintaining intraverbal chains, however, have not been examined experimentally. Saporta (1963) has undertaken an evaluation of three grammatical models in the teaching of foreign languages which should prove illuminating in this respect. Sapon's "reflections on models of linguistic structure and language programming" (1961b) reflect, as well, the synthesis of analytical and functional approaches to patterning adopted by many language programmers:

> "What has generally emerged from my own experience in programming Spanish is the recognition that the straight 'economical' line of language description [in linguistics] is neither the shortest nor the most direct route to student performance in the language being taught. What does seem to offer much promise is a first approach to the language via a series of transformations and expansions of basic sentence material. This material can then be sequenced to exploit usable existing habits and to avoid conflicting ones ... a

kind of contrastive psycholinguistic grammar ... and finally fixed through the use of pattern and substitution drill" (p. 6).

In view of the widespread use of drill to condition intraverbal patterns, it is unfortunate that this technique has not been put to careful laboratory test. Under controlled conditions, it would not be surprising to find sheer repetition minimally effective. This technique should be contrasted with that of programming, in which gradual progression and the development of abstraction through multiple examples replaces repetition. Skinner (1960) has contended that no one learns by repeating: "he may learn so little that he needs to repeat and will learn more upon successive occasions, but the repetition itself is not involved" (p. 174). "Stamping in" or "fixing" through repetition alone has not been found to be an effective technique for the control of behavior in the laboratory.

Intraverbal relations *between* first and second language comprise translation for the beginning student.

> "Faced with a passage in the new language, the translator emits appropriate intraverbal responses. If these fall into something like a familiar pattern, he may then react in any or all of the ways appropriate to a listener ... Eventually the translator improves upon this crude prodedure by developing more efficient intraverbal operants, mainly of larger patterns, and by acquiring normal listening or reading behavior under the control of the new language without the aid of translations" (Skinner, 1957, p. 77).

Several language programmers agree that, whereas the evocation of formal repertoires in English interferes with the development of these repertoires in the second language, the evocation of intraverbal relations between the languages hinders not only the maintenance of formal repertoires in the second language but also the development of intraverbal chains in that language. Mueller (1961) writes: "Developing automatic control over the sound patterns of the language is retarded when the student s attention is directed toward meaningful utterances" (p. 43). A similar statement by Morton (1960) has been quoted earlier. (Also see T. Mueller, 1962.)

On the other hand, some programmers have argued for and implemented the early introduction of thematic repertoires such as translation (intraverbals) and question-and-answer (mands), on the grounds that motivation is sustained or enhanced by this procedure. Presumably, the reinforcing consequences of acquiring an intraverbal repertoire such as translation derive initially from the fact that the student may react to his own speech in his native language as a listener.

It remains to be shown by controlled experiments whether the introduction of thematic repertoires does in fact impair the formal repertoires established earlier; if interference is demonstrated, we need to know the sources and their relative importance. The greatest difficulty in this kind of research is accurate specification of the dependent variable – the accuracy of the formal repertoire. Subjective techniques of evaluation are undesirable but acoustic specification of the stimulus and the response is at present unwieldy. It may not be premature, however, to undertake to assess the effects of introducing thematic repertoires on the *prosodic* features of formal repertoires, measured electronically.

Any of the four formal repertoires may serve as the vehicle for the acquisition of thematic repertoires such as intraverbals. Some programs employ a written stimulus and written response. These include a program in Hebrew by Hammond (1962), one in German by Ferster and Sapon (1960), and a computer-based program to condition Russian vocabulary by Licklider (1962). Valdman (1964), Moraud (1961), Harris (1961), and others condition intraverbal responses by means of dialogues supplemented by English translation. A Latin program by W. E. Sweet (1961) employs a less common procedure: a written stimulus is connected intraverbally to a spoken response. Most of the available second-language programs, however, condition spoken second-language stimuli to spoken English responses. Morton describes the procedure employed in his Spanish program as follows: "Practice rather than theory guided us in assuming that once the structural clues of Spanish had been mastered ... the student, working with the minimal meanings afforded him by these in each new utterance, could be expected to 'fill in the gaps' with the help of 'broad hints' in English (i.e., nonliteral translations)" (1960, p. 23).

Although most language programmers and teachers would agree that literal translation is not the solution to the problem of how to introduce an intraverbal repertoire most effectively, the available alternatives also seem unsatisfactory; these include non-literal interlinear translations, alternate pages of English and second-language texts, tape-recorded second-language phrases with their English "equivalents" in the text, paired associate learning with flash cards or lists, and so forth. Morton's "broad hint" approach, cited above, shows greater promise; it is related to a variably-blurred prompting technique, developed by Israel (1960) to study vocabulary learning. The auditory analog of Israel's technique would be worth exploring: English prompts might be recorded on a tape track parallel to one containing foreign-language narrative or questions. The prompts could be masked by a noise whose level was under the student's control, or the prompts could be faded over the course of the recorded program by the experimenter, or both.

The crucial difficulty with all these techniques, however, is the attempt to transfer a response from one functional class to another. Initially, the student says "apple," for example, as a simple and well-conditioned textual or echoic response to the English "apple." It is desired, however, that this response come under the control of (be evoked by) a formally *dissimilar* stimulus, e.g., the spoken or written "manzana." *That* association has no status in the student's native language. It is not surprising, therefore, that as long as the translation is available the English stimuli arrogate control of the English responses. Without the translation, however, there is no reason initially for the response "apple" to occur in the presence of "manzana."

One solution to the apparent paradox is to evoke the English responses by means of collateral stimuli that do not exercise extensive control over these responses, and then to fade these collateral sources of strength as the intraverbal linkages between the two languages become established. This formula seems to characterize the ingenious technique developed by Shaefer (1961) to condition English intraverbal responses to German text. [6] Among the collateral sources of strength for a response to English text, there are, in addition to thematic prompts, intraverbal prompts provided by the syntactic structure and by common phrases, as suggested earlier. These collateral sources of strength are nicely illustrated by the procedure for generating order-approximations to English with successive subjects, employed by Miller & Selfridge (1953). The redundancy of the text is one way of expressing the degree of control exerted over responding by collateral sources of strength. Consequently, when Schaefer replaces high-redundancy words in the English text with their German counterparts, as in "But why will you say that ich am mad?," the correct intraverbal is emitted and it is emitted in the presence of the German textual stimuli. It remains to fade these collateral sources of strength by replacing both more words and words of lower redundancy. For example, the above excerpt is soon followed by "Ich heard all things ..." where "I" is less determined by context. In six pages the text works up to "Es war laut, aber es grew lauter, ich say, lauter every moment!"

The auditory analog of this procedure for conditioning intraverbal responses would be worth trying and might prove superior on at least two counts. First, Schaefer's procedure evokes English pronunciations of the German words, because of the common orthography employed and because German words are interspersed at varying intervals among the English words in the text. If echoic rather than textual behavior were employed, there would be less tendency for English pronunciation of the German words to occur and, because the stimulus and response-product in echoic behavior are formally similar, it would be possible to discriminate the improper pronunciations. This is not possible in textual behavior, as emphasized earlier. The second potential advantage of an auditory adaptation of Schaefer's technique is the greater number of collateral sources of strength that may be manipulated. In addition to the intraverbal and thematic cues available in text, there is a multiplicity of acoustic cues, including stress, intonation and tempo, which may be used as prompts and vanished as necessary.

Tacts

The tact is a class of verbal operant characterized by a three-term relation: nonverbal discriminative stimulus, verbal response, generalized reinforcement.

[6] The technique has been used, perhaps independently, by VanRiper and Smith (1962) in conditioning a textual repertoire: reading phonetic script.

"The three-term contingency in this type of operant is exemplified when, in the presence of a doll a child achieves some sort of generalized reinforcement by saying *doll;* or when a teleost fish, or picture thereof, is the occasion upon which a student of zoology is reinforced when he says *teleost fish*" (Skinner, 1957). Tacting comprises a large part of the thematic repertoire in first-language learning and a minute part in second-language learning; in the latter case, intraverbal responses "carry the thematic load" (vide Brethower, 1961). Instead of conditioning the response "manzana" with some generalized reinforcer in the presence of an apple or a picture thereof, the response is conditioned as an intraverbal to textual or auditory stimuli, such as: "Say 'apple' in Spanish," or "Eva comio una manzana envenenada." Once again, the means by which a thematic repertoire is taught in second-language learning is to establish one sort of functional control and hope for transfer to another. Thus, when the student eventually confronts an apple and it is appropriate to say "manzana," we do not expect him to be speechless in the face of this novel situation; we expect manzana-the-intraverbal to become manzana-the-tact. The transfer of functional control presumably occurs through mediated generalization; that is, at the first confrontation the tact "apple" is emitted covertly, and "manzana" is uttered aloud as an intraverbal to "apple." If this leads to some sort of reinforcement on a number of occasions, "manzana" will acquire the functional properties of a tact.

The mediating responses in the student's native language, required by this approach to the conditioning of tacts (i.e., transfer from intraverbal control), probably impair the acquisition and maintenance of second-language fluency. Carroll (1962) concludes in a survey of research that "foreign words are best learned (and probably better retained) when presented in association with the objects, actions, qualities, and conditions which are their referents." Several programs employ pictorial material to this end (e.g., Marty, 1962); much greater versatility is provided by educational television (Barcus et al., 1961) and specialized audio-visual devices (Carroll, 1963a; Porter, 1958).

The direct approach to conditioning second-language tacts, however, also faces several problems. First, it is difficult to maintain these tacts outside the classroom, where the student responds to his environment in his native language. Second, the nonverbal controlling stimulus may evoke English responses that will interfere with both the formal and thematic properies of the second-language tact.

The nature of thematic interference between first- and second-language tacts is well-revealed in an experiment by Lenneberg (1957) on learning color names in six different experimental "languages." The languages consisted of four color words and the subject's task was to discover the "meaning" of the words by observing their use by the experimenter. The nonsense words of the first language were distributed over the Munsell color series exactly as the English words: brown, green, blue, and pink. The other five languages had words whose frequency distributions (generalization gradients) represented systematic distortions from the previously established English distributions. There were two types of distortions: of the slope of the gradients (increasing or decreasing the determinacy of the color names), and of the location on the physical continuum (making colors which in English have no specific names a perfect example of a color category in the nonsense language). Lenneberg found that if the tact generalization gradients ("reference relationships") of English were undistorted in the second language, the color words in that language were learned most easily; if only the locations of the gradients on the stimulus continuum were distorted, a small impairment in learning was observed. Learning the color names was most retarded when the shapes of the English color gradients were distorted in the second language to yield gradually rising slopes, that is, less well-defined boundaries between stimulus classes.

Mands

A mand is a verbal operant in which a response of a given form is reinforced by a characteristic consequence. The major variables that control a mand are the level of deprivation or of aversive stimulation applied to the speaker and his reinforcement history for similar responses. Questions, commands, entreaties, and the like are characterized by this kind of functional control (*vide* Skinner, 1957). Mands are difficult to condition in a self-instruction setting because an active listener, required to present appropriate reinforcement, is not available. It is unwieldy, if not impossible, to arrange characteristic reinforcing consequences, such as providing the time if the student should inquire, or complying with a command such as "stop," or granting an entreaty, and so forth. As was the case with tacts, the functional class of mands is largely neglected in second-language programming in the hope that, when deprivation or aversive stimulation occasions a mand, the transfer of certain intraverbals will take place. As is the case with tacts, this "slight of mand" presumably depends on mediated generalization, which may be a mixed blessing, facilitating the thematic accuracy of the response but degrading its formal properties. Although several second-language programs, notably those of Lermontoff (1961), Morton (1960), and Rocklyn and Moren (1962), indirectly condition mands by conditioning intraverbals of appropriate form (e.g., "ask for an apple in Spanish"), this may not be the only way of proceeding. An audio-lingual program could be so carefully sequenced that the occurrence of particular mands by the student was predictable and, therefore, the characteristic (verbal) reinforcers could be prerecorded on the master tape.

TRANSFER WITHIN AND BETWEEN REPERTOIRES

The concept of transfer has played a large role in this disquisition on programmed learning of a second language; it has turned up as an observation, an explanation, and an assumption at many points, so it may be well to summarize the sources of transfer available to, and often relied upon by, the second-language programmer. In echoic behavior and dictation, transfer of first-language auditory discriminations will occur, enhancing the acquisition of discriminations between sound classes but impeding the learning of equivalences (generalization) within these classes. The typical effect is over-discrimination and the emphasis in conditioning must be on the equivalences among discriminably different sounds. In textual behavior and transcription, transfer of first-language orthographic discriminations will occur when the second language employs an orthography that overlaps with that of English.

In echoic and textual behaviors, transfer of the differentiated vocal repertoire of the student's first language will occur to the degree that the two languages share a similar sound system or orthography. This greatly expedites the acquisition of a rough approximation to the desired repertoire, but it impedes the development of accurate pronunciation to the degree that the first- and second-language vocal repertoires differ. The consequences of transfer are similar for the differentiated manual repertoire involved in dictation and transcription.

A textual response will transfer to an echoic repertoire if the relevant auditory discriminations have been conditioned, and the converse can occur if the necessary orthographic discriminations have been learned in the first- or second-language. Similarly, transfer may occur between dictation and transcription if the relevant discriminations have been acquired. In complementary fashion, the student with an echoic repertoire should more readily acquire dictation when taught how to write the orthography than one who does not possess that repertoire; a similar transfer of discriminations may be expected to occur between transcription and textual behavior. These transfer effects are most obvious when the second-language orthography differs from that of the student's native language.

Within the thematic repertoires, an intraverbal response may transfer to the status of a tact in the second language; this requires non-verbal stimuli that evoke tacts in the student's native language which are linked intraverbally to responses in the second language. Intraverbal responses may similarly transfer to the status of mands in the second language when deprivation or aversive stimulation makes a mand likely and first-language responses intervene.

Transfer also takes place between the formal and thematic repertoires. A spoken response, whose form was conditioned during the acquisition of a purely echoic or textual repertoire, can take on the functional properties of an intraverbal through the replacement of one kind of stimulus control (formal) for another (thematic). This intraverbal response may then become a tact or a mand, in the manner described above. Similarly, written responses, learned as a part of the formal repertoires dictation or transcription, may transfer to the thematic repertoires under suitable conditioning procedures.

Finally, I should note that the formal and thematic repertoires acquired in the language laboratory and in the language classroom do transfer, in some measure, to the second-language community.

SUMMARY TABLE OF SECOND-
Available and

Authors	Language	Behaviors Receiving Major Emphasis						
		Formal Repertories				Thematic Repertories		
		Echoic	Textual	Transcription	Dictation	Intraverbal	Tacts	Mands
Carroll	Chinese	x	x	x	x	x	x	x
Chou & Peterson	Chinese	x				x	x	x
Garvey & Clark	Chinese	x				x		x
Burroughs	French	x			x			
Mueller	French	x			x	x	x	x
Hanzelli	French	x	x	x	x	x	x	x
Lermontoff	French	x	x			x		x
Marty	French	x	x	x	x	x	x	x
Moraud	French	x	x	x	x	x	x	x
Ricket & Dubois	French	x		x		x		x
Valdman	French	x			x	x		x
Eilert	German	x	x	x	x	x	?	?
Ferster & Sapon	German			x		x		
Liedke	German	x	x	x		x		x
Ventola & Wilson	German			x		x		
Bloom & Smith	[illegible]brew		x	x		x		
Hammond	Hebrew			x		x		
Sweet	Latin			x	x	x		x
Thilson	Latin		x	x		x	x	x
Licklider	Russian			x		x		
Myers	Russian	x	x	x	x	x	x	x
Morton, Mayer, & Brethower	Russian	x			x	x	x	x
Rocklyn, Moren, & Zinovieff	Russian	x				x		x

* This summary of available language programs is based on a survey conducted by the author in August, 1963. Additional information and listings may be found in the reference: Center for Programmed Instruction (1962).

LANGUAGE PROGRAMS*
In Preparation

Special Presentation Device	Approximate Hours to Completion	Location of Research	Comments and Source	S = Study discussed here E = Evaluation data reported
yes	undetermined	Harvard Univer.	Carroll, 1963a	S
yes	200	Univer. of Michigan		
tape recorder				
tape recorder	14–16	Encyclopedia Britannica Films		
yes	250	Univer. of Michigan		
tape recorder	year course	Univer. of Washington		
yes	200	Center for Programmed Instruction		S
yes	year course	Hollins College	Marty, 1962	S
tape recorder	year course	Hamilton College	Blyth, 1961	S, E
no	18–23	General Program Teaching Corporation	Carroll, 1962	
tape recorder	year course	Indiana	Valdman, 1964	S, E
tape recorder	60–75	Encyclopedia Britannica Films	Carroll, 1962	
no	48	Harvard Univer.	Ferster & Sapon, 1960	S, E
tape recorder	year course	Hamilton College	Blyth, 1961	S, E
no	17–30	TMI-Grolier	Carroll, 1962	
no	15–25	TMI-Grolier	Carroll, 1962	
no	48	Princeton Univer.	Hammond, 1962 Biblical material	S, E
tape recorder	two year course	Univer. of Michigan	Sweet, 1962	S
no	undetermined	Center for Programmed Instruction		
computer based	undetermined	Bolt, Beranek, & Newman	Licklider, 1962	S
yes	1/2 year course	Earlham College	Smith, 1963	S, E
yes	275	Univer. of Michigan		
tape recorder	140	George Washington Univer.	Rocklyn, Moren & Zinovieff, 1962 Limited tactical language	S

Authors	Language	Behaviors Receiving Major Emphasis						
		Formal Repertories				Thematic Repertories		
		Echoic	Textual	Transcription	Dictation	Intraverbal	Tacts	Mands
Saltzman	Russian	x	x	x	x	x		x
Wilson & Ventola	Russian			x		x		
Barcus	Spanish			x		x		x
Gilbert	Spanish		x	x		x		
Harris	Spanish	x	x	x	x	x		x
Morton, Mayer, & Brethower	Spanish	x			x	x	x	x
Sapon	Spanish	x	x	x	x	x	x	x
Sullivan	Spanish	x	x	x	x	x	x	?
Universal Teaching Machines	Spanish	x	x	x				x
Wilson & Ventola	Spanish			x		x		
Morton, Mayer, & Brethower	Thai	x				x	x	x
Fiks & Garvey	Vietnamese	x				x		x
Details not available for								
Bailey	Latin							
Newmark	French							
Unknown	Spanish			x		x		
Unknown	French							
Unknown	Spanish							
Unknown	German			x		x		
Unknown	Hebrew							
Unknown	Russian			x				
Unknown	Russian							
Koppitz	German			x		x		
Allen	English							

Special Presentation Device	Approximate Hours to Completion	Location of Research	Comments and Source S = Study discussed here E = Evaluation data reported	
tape recorder	1/2 year course	Indiana Univer.	Saltzman, 1963	
no	18—22	TMI-Grolier	Carroll, 1962	
no	20	Denver Public Schools	Carroll, 1962	
no		TOR Labs	Carroll, 1962	
tape recorder	260	Louisiana State Univer.	Harris, 1961	S, E
yes	225	Univer. of Michigan	Morton, 1960	S
tape recorder	50—85	Encyclopedia Britannica Films	Carroll, 1962	S, E
tape recorder	40—45	Encyclopedia Britannica Films	Carroll, 1962	S, E
tape recorder	24—35	Universal Electric		
no	17—30	TMI-Grolier	Carroll, 1962	
yes	200	Univer. of Michigan		
tape recorder		George Washington Univer.	Fiks & Garvey, 1963 Limited tactical language	S
		Hollins College		
		Systems Development Corporation		
no	year course	AVTA Corporation		
		American Teaching Systems		
		American Teaching Systems		
no		AVTA Corporation		
		AVTA Corporation		
		AVTA Corporation		
		International Teaching Systems		
computer based		IBM	Uttal, 1962	
		Thompson Ramo Woolridge		

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