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ABSTRACT

A self-instructional device for conditioning accurate prosody in second-language learning is described in this article. The Speech Auto-Instructional Device (SAID) is electro-mechanical and performs three functions: SAID (1) presents to the student tape-recorded pattern sentences that are considered standards in prosodic performance; (2) processes the student's imitation and instantaneously evaluates its acceptability on the basis of pitch, loudness, and tempo; and (3) displays the degree to which the imitation is unacceptable and demonstrates how modifications are to be made for correction. Discussion of the rationale for the SAID system includes comments on other approaches to prosody instruction. Detailed information on SAID's functional operation is provided. (RL)

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A SELF-INSTRUCTIONAL DEVICE FOR CONDITIONING ACCURATE PROSODY [1]

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Intonation, accentuation, rythme constituent l'aspect prosodique d'une langue.

Chaque langue a des caractéristiques prosodiques qui lui sont propres; une maîtrise suffisante de ces caractéristiques par un étudiant étranger fait partie intégrante d'une "bonne prononciation".

Ni les méthodes d'enseignement traditionnelles, ni celles qui utilisent le laboratoire de langues, ni même celles qui se réclament de l'Enseignement Programmé ne sont parvenues jusqu'ici à assurer chez les étudiants une reproduction satisfaisante des traits prosodiques de leur langue d'étude.

Un appareil mis au point à l'Université de Michigan paraît en mesure d'améliorer radicalement la situation.

En effet, cet appareil (appelé SAID, Speech Auto-Instructional Device) évalue la production d'un sujet (en réponse à un modèle sonore) au triple point de vue de la *hauteur,* de la *force* (intensité) et du rythme et lui transmet immédiatement les résultats de cette évaluation.

En suivant les mouvements d'une aiguille sur un cadran, le sujet est tenu constamment informé, pour chacun des trois paramètres, de l'amplitude et de la direction des déviations commises. Quand la production du sujet est "acceptable" (c'est-à-dire quand elle se situe dans certaines limites déterminées à l'avance), pour l'un des paramètres considérés, l'opération est répétée pour le paramètre suivant etc.... Quand la production du sujet est acceptable pour les trois paramètres choisis, la machine présente un nouveau modèle.

En plus de son utilité pratique comme instrument didactique, le SAID permettra de recueillir des renseignements précieux sur les processus généraux de l'apprentissage verbal.

Intonation, Akzent und Rhythmus bilden die Prosodie einer Sprache.

Jede Sprache hat ihre eigene Prosodie; die Beherrschung ihrer Eigenarten bildet einen wesentlichen Teil der „guten Sprache", deren sich ein Fremdsprachenschüler befleißigen sollte.

Weder die traditionellen Unterrichtsmethoden, noch die Kurse im Sprachlabor, noch auch der sogenannte programmierte Unterricht haben es bisher fertiggebracht, dem Studenten eine einwandfreie Beherrschung der prosodischen Merkmale einer Sprache bereits im Anfangsstadium des Unterrichts zu vermitteln.

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[1] An address to the International Congress of Applied Psychology, August, 1964. The Center for Research on Language is supported by the Language Developement Research, U. S. office of Education.

Ein in der Universität Michigan gebauter Apparat scheint nunmehr diese Probleme ein für allemal zu lösen.

Der sogenannte SAID (Speech Auto-Instructional Device) vergleicht die Aussprache eines Sprechers mit einem vorgegebenen Klangmodell in Bezug auf Intonationskurve, Intensität und Rhythmus und gibt die Ergebnisse dieses Vergleiches bekannt.

Ein Zeiger läuft über ein Zifferblatt und gibt durch seinen Ausschlag die Abweichung vom Standardmodell der Aussprache des betreffenden Beispiels an. Bleibt die Abweichung innerhalb einer bestimmten zuvor festgesetzten Grenze, so wird nach sukzessivem Vergleich der 3 obengenannten Parameter das nächste Modell vorgenommen usf.

Neben seinem praktischen Wert für den Sprachunterricht dürfte der vorgestellte Apparat auch wichtige allgemeine Ergebnisse über die Spracherlernung liefern.

The achievement of native-like fluency in a second language is as uncommon and arduous as it is essential to effective social behavior in a foreign land. Social custom generally accords the novice who is acquiring a set of skills—whether in sports, cooking, warfare, or education—both indulgence and encouragement, but this is not the fare of a novice speaker of a second language. Native speakers of the language view him with suspicion at least, and at worst with ridicule and hostility. Perhaps this is because of the central importance of language in almost every aspect of social life. Indeed, philosophers have contended that language is the defining property of man; the layman's tendency to view his *own* language as the defining property of man may have the same sources. Mark Twain entertainingly reveals the vital social role of fluency in the language of the community in this dialogue between Huck Finn and his friend Jim:

"Looky here, Jim; ain't it natural and right for a cat and a cow to talk different from us?"

"Why, mos' sholy it is."

"Well, then, why ain't it natural and right for a Frenchman to talk different from us? You answer me that."

"Is a cat a man, Huck?"

"No."

"Well, den, dey ain t no sense in a cat talkin' like a man. Is a cow a man? —er is a cow a cat?"

"No, she ain't either of them."

"Well, den she ain't got no business to talk like either one er the yuther of em. Is a Frenchman a man?"

"Yes."

"Well, den! Dad blame it, why doan' he talk like a man? You answer me dat!"

What can be done to teach a Frenchman, or an American, or a Yugoslav to "talk like a man" when he is among men who talk in a language different from his own? Clearly, the speaker must master the component speech sounds of the second language, their permissible patterns in grammatical utterances, and the appropriate occasions for these utterances. Without these complex skills he will often be unintelligible (Lane 1963a), and so it is these skills that receive the lion's share of research and pedagogy. However, intelligibility is only a part of the story of fluency in a foreign language. This report of research is concerned with another set of skills, relatively independent of the first, which contributes little to intelligibility and everything to fluency, and thus to social acceptance. Native-like fluency in a second language is predicated on a mastery of its patterns of intonation, stress, and rhythmn -in short, a mastery of its prosody.

Phonetic descriptions of numerous and diverse languages reveal a variety of highly stylized patterns of stress and intonation. The novice speaker of a second language who employs the prosody of his native tongue is very likely to sound foolish, even if his first and second languages have common historical roots and belong to the same language family. Recent acoustic studies of language prosody[2]) confirm and amplify the phonetic descriptions. Again, the theme is diversity among languages and stereotypy within them. Delattre (1962a), for example, has extracted the characteristic intonation contours for declarative sentences shown in Fig. 1 from spectrographic analyses of conversations in four languages. Among other contrasts, American intonation seems to be characterized by a recurrence of falling contours, whereas the motif of German, Spanish and French is the rising contour. Similarly, there are characteristically different patterns of stress among languages. Concerning these four languages, for example, Delattre provides evidence that in French the stress is characteristically on the final syllable, whereas in Spanish it falls on the next-to-last syllable, while English and German vary between these two loci. The temporal patterns of responding, that is, the rhythmic characteristics of different languages, have received little study, but the covariance of duration and stress in several languages is well documented (e.g., Liebermann, 1960), and it is not unlikely that future research will also reveal stylized patterns in the temporal spacing of speech segments.

It is axiomatic for the present report, then, that languages differ in their prosody and that the speaker who has not mastered the prosody of a second language is not fluent in that language. Before describing our approach to conditioning prosodic skills in a second language, it is desirable to review briefly the alternative approaches that have been employed—largely unsuccessfully—in the past. We restrict our attention to teaching prosodic accuracy to an adolescent

[2]) Dreher (1951), Goodman (1952), Fry (1955, 1958), Malmberg (1956), Bolinger (1958a, 1958b), Bascom (1959), Jassem (1959), Garding & Gerstman (1960), Lehiste (1960, 1961), Lieberman (1960), Delattre (1961, 1962a, 1962b), Goldman – Eisler (1961), Hadding – Koch (1961), Rigault (1962), Lindblom (1963), Magdics (1963).

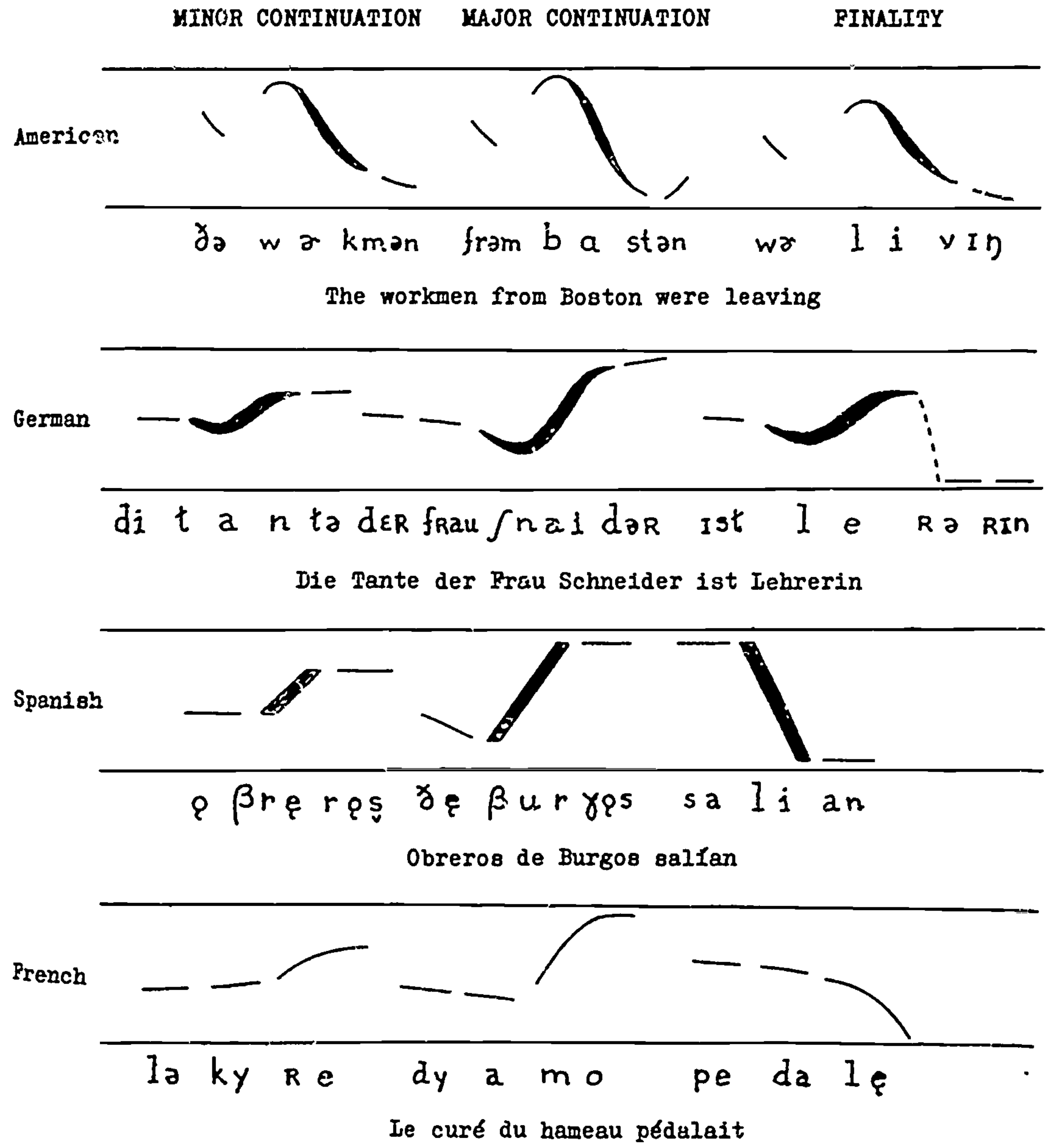

Figure 1. Characteristic intonation contours of declarative sentences spoken in American English, German, Spanish, and French. (From Delattre, 1962a)

or adult while he resides in his native land, with all the sources of resistance to the learning of new habits of speech that this implies (Lane, 1962a). First, and most common, there are the techniques available to the language teacher in the traditional classroom setting. In this case, prosodic skills literally go by the board; they are rarely acquired well. Several constraints on language learning in the classroom militate against the acquisition of prosodic skills: the widespread conviction among college students that a language block is a place of execution; the broad objectives of the language course, often ranging from culture through literature to spelling; the large number of students confronting each teacher; the eddy of second-language behaviors created amidst a sea of first-language habits, and so forth (Lane 1964, 1965). Rarely are the avowed ingredients of learning in evidence: active responding by the individual student, differential feedback or "reinforcement" depending on the accuracy of his responses, and careful sequencing of each component task according to the student's individual level of proficiency at the moment (Lane, 1963b). Moreover, the intrinsic complexity of prosodic features, extending as they do over several segments of an utterance, presents a special measure of difficulty to their attainment by classroom instruction. Little wonder if the language teacher is pleased when in two or three years a student learns the segmental sounds, some vocabulary, and the elements of reading and writing in the second language. If he doesn't sound like an authentic Frenchman, well, after all, he's not one.

When choral work in the language classroom is supplemented by sonic treatments in the language laboratory, the gain in learning is small [3]). Simple exposure is no more effective than it is plausible as a basis for learning (Lane, 1962b). In a few language laboratories there is provision for active responding by the student and in a lesser number he may even hear his poor pronunciation played back to him repeatedly. The student is typically in no position to evaluate his pronunciation, however, since the novice speaker is usually a novice listener. Even if the student were able to discriminate between good and poor pronunciation, these have no differential effects in the immediate environment. When audible differences don't make a difference, both discrimination and production fail.

The third and most recent approach to language pedagogy is programmed instruction (Lane, 1965). The application of programmed instruction has necessarily involved a molecular functional and linguistic analysis of the behaviors involved in language learning. Based on this analysis, new techniques for controlling the learning process have been applied to rendering it more effective and efficient. Once again, however, the conditioning of prosodic features has largely been overlooked. None of the language programs described in several recent and comprehensive surveys explicitly states prosodic accuracy as an objective, nor does any of these programs explicitly provide for the conditioning of the prosodic features, although all, of course, do battle with the segmental features and with vocabulary. The obstacles to employing programmed self-instruction as a means for conditioning prosodic accuracy are these: The student must be taught to discriminate between accurate and inaccurate prosody in the first place; then, these discriminations must be maintained during the acquisition of productive skills; finally, the student must apply the discriminations to his own vocal behavior—reliably and validly. No language program has yet tackled, still less overcome, these obstacles.

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[3]) Lewis (1961), Reichard (1962), Keating (1963), Hutchinson & Gaarder (1964), Scherer (1964).

From the ashes of these unsuccessful methods for conditioning prosodic accuracy in a second language emerges a pedagogical phoenix with rather special plumage. An instructional method is required that will: 1. *provide the student with rapid, reliable, and valid evaluations of his prosodic accuracy,* and 2. *adapt the learning sequence in accord with the student's proficiency at each step along the way.* These pedagogical requirements led to the development, at the Behavior Analysis Laboratory, of a device called SAID, the Speech Auto-Instructional Device.

SAID is an electro-mechanical device which performs three significant functions in conditioning prosodic accuracy in a second language[4]). First, SAID presents to the student tape-recorded pattern sentences that are considered standards in prosodic performance. These sentences are programmed in the best known sequence for teaching prosody in the target language to a speaker of a given native language. The student is instructed to imitate the pattern sentence after he hears it. Second, SAID processes the student's imitation, and instantaneously evaluates its acceptability on the basis of its three distinct prosodic features: pitch, loudness, and tempo. Third, SAID immediately displays to the student the degree to which his imitation is unacceptable, and demonstrates how he must modify his next imitation, in the prosodic feature under consideration, in order to make the imitation more acceptable. This process of presentation-evaluation-display repeats itself until the prosody of the student's imitation is acceptable.

The first phase of the three-fold machine process is the presentation of the tape-recorded pattern sentences. The sequence of patterns presented to the student is controlled by the computer base of SAID (Fig. 2), which instructs the tape recorder to rewind when the imitation is unacceptable or to play the next pattern when the imitation is accurate.

The second phase, evaluation, is accomplished both by the computer and by analog electronic equipment. The speech signals from the tape recorder and the student's response microphone are channelled to analog extractors of the acoustic parameters (Fig. 3). The conceptual bases for the parameter extractors were contributed by the University of Michigan's Communication Sciences Laboratory. The fundamental frequency, the major contributor to the perception of pitch in speech (Lane, 1962c), is extracted by filtering each of the speech signals into two ranges within the entire fundamental-frequency spectrum of the human voice. The range containing the fundamental is selected by switching circuitry and the signal from the selected range is sent to a frequency-to-voltage converter. The output of the converter is a dc voltage that varies linearly with the fundamental frequency of the speech signal. In this form it is digitized and processed by the computer.

[4]) A more detailed and technical account of the operation of the SAID system will be found in Lane and Buiten (1964).

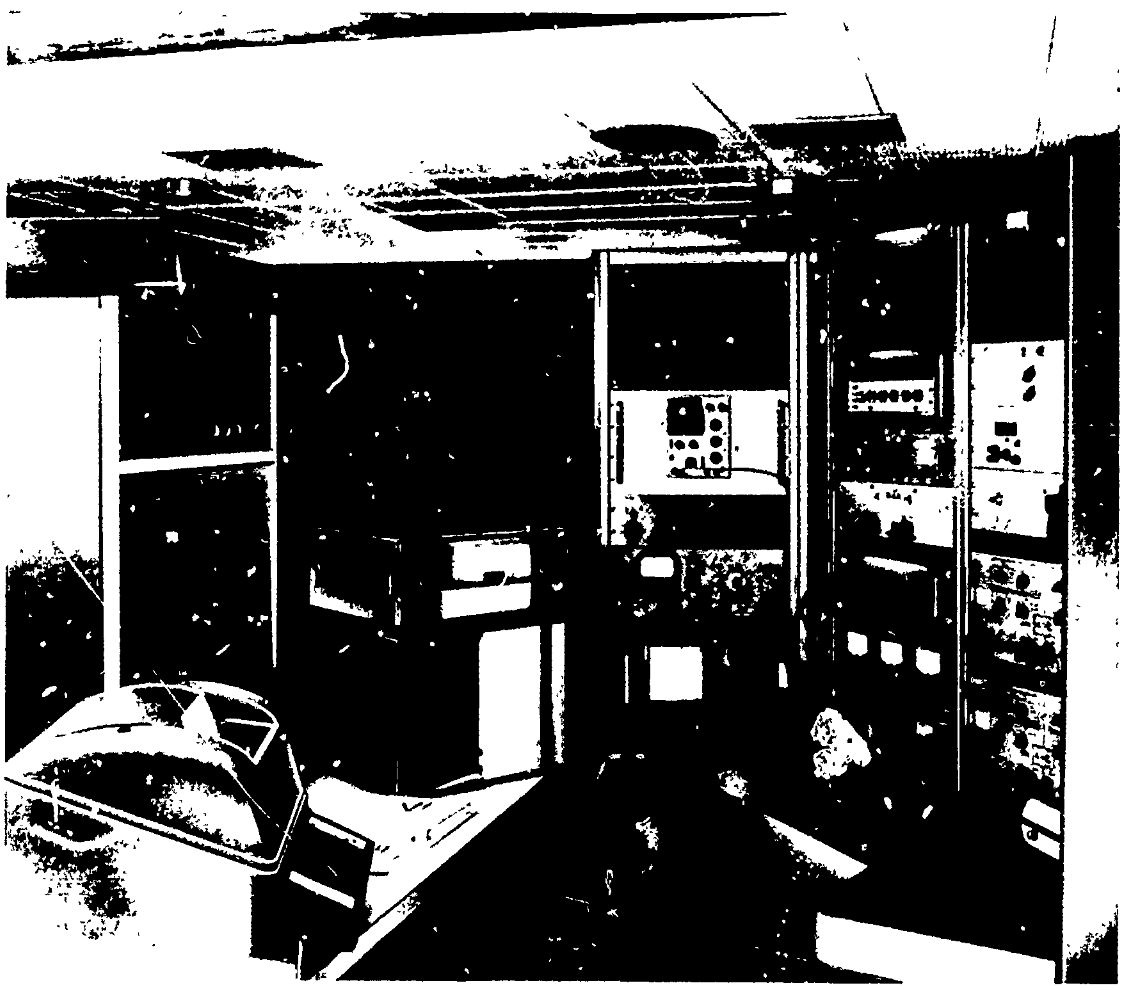

Figure 2. Experimenter's console, SAID system. The photograph shows the computer base of the system with teleprinter output (left), tape-reader input, monitoring equipment, parameter extractors, and tape recorder (extreme right).

The intensity of the speech signal, the major contributor to the perception of loudness (Lane, Catania & Stevens, 1961), is extracted by rectifying and filtering. This produces a dc voltage which varies linearly with the amplitude envelope of the speech signals. This dc voltage is digitized and processed by the computer. While processing the intensity parameter, the computer also records the time elapsed between successive intensity peaks.

The student has not been trained, and therefore is not able, accurately to interpret changes in frequency, intensity, and temporal spacing, since changes in these physical parameters do not produce simply corresponding changes in their apparent or psychological values. The student can, however, be expected to discriminate readily variations in the psychological effects of these physical parameters: pitch, loudness, and tempo. Therefore, the computer samples the output of the parameter extractors, selectes one representative (peak) value of frequency and intensity for each burst of speech energy (usually a syllable), measures the time between intensity peaks, and converts these linear physical

Figure 3. Analog electronic equipment, SAID system. (Top to bottom, left to right: test oscilloscope, mixer, frequency-to-voltage converter, monitor recorder, playback amplifier, amplifiers for parameter extraction, intensity extractor, error monitor meters, computer input amplifier, voice-operated relay, power supply, switching circuitry and filter bank for extraction of fundamental frequency, switching circuitry for mode selection, tape recorder.)

values to logarithmic psychological units according to the psychophysical functions for speech production and perception determined in earlier research (Lane, 1962c). The variation of these psychological values more accurately represents the prosodic features of speech from the point of view of the student and his language community. While the pattern sentence is presented to the student, the values of its psychological parameters are stored away in the memory of the computer. While the student is imitating the pattern, the psychological parameter values of his imitation are compared to corresponding stored values of the pattern, and three error scores are generated. To perform this operation, the computer solves the following equation:

$$e = [\log S_i - \log S_o] - [\log M_i - \log M_o],$$

where e is the error fed back to the student on his panel meter, S_i is the i^{th} value of the student's imitation for the feature being evaluated, S_0 is the *first* imitation value to which all others are referred, and M_i and M_0 are corresponding values of the model pattern. It is this manipulation that makes the error readings for each speaker relative to his own first utterance; the pitch, loudness, and tempo values are normalized so that conditioning is based on the dynamics of prosody rather than on the absolute acoustic values of prosodic parameters. The error scores are compared to preset criteria of acceptability for the three features. The results of these acceptance tests determine the sequence of presentation and display.

The third phase of the machine process involves displaying the results of the comparison of pattern and imitation, and the results of the acceptance tests. The display of the comparison difference is made on a zero-center meter, so that both the direction and magnitude of error score can be monitored readily. The student's error score for one of the three features is displayed to him immediately after the error is made (Fig. 4). A neon indicator on his panel shows him which

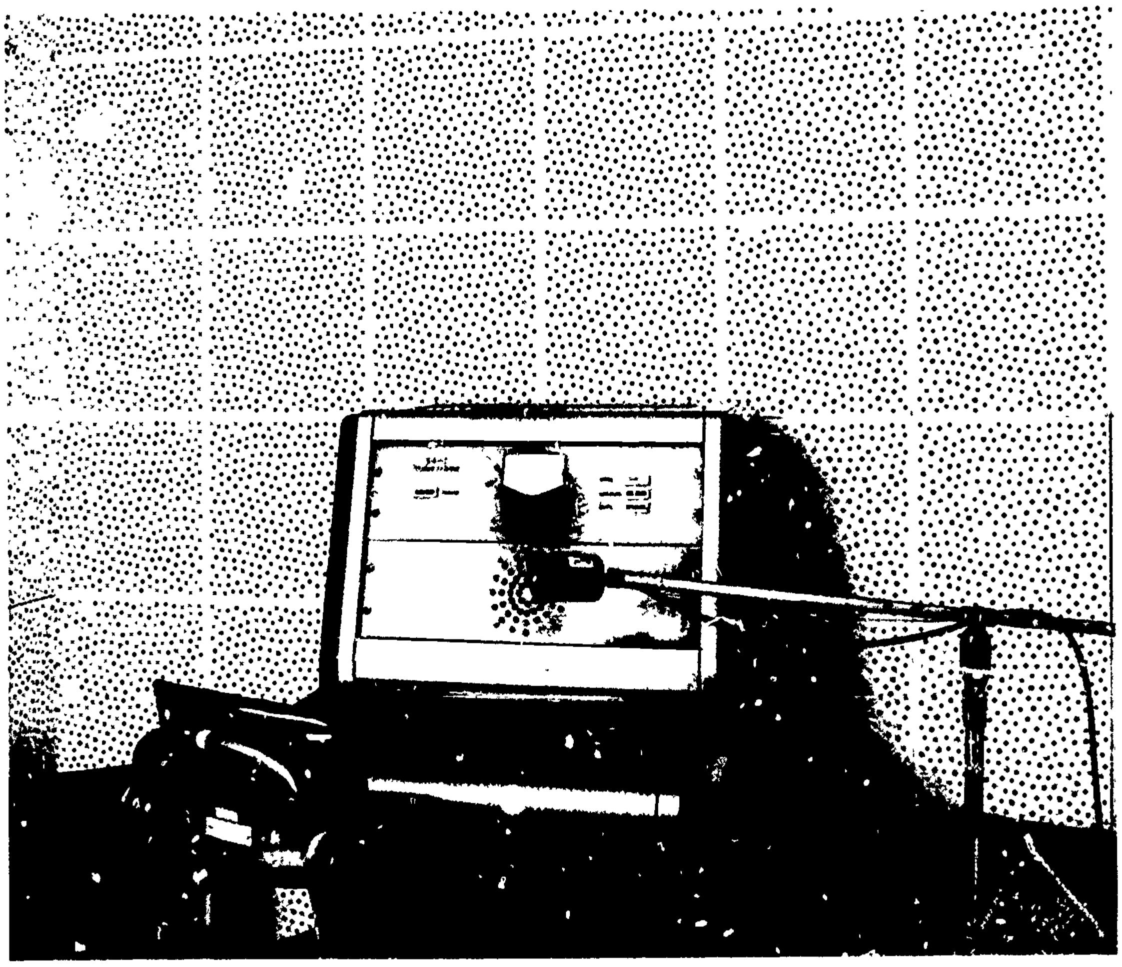

Figure 4. Student booth, SAID system. The photograph shows the loudspeakers for presentation of the pattern sentence, the microphone that receives the student's imitation, and the student console (left to right: respond light, error display, mode indicator).

feature is being displayed on each trial. When the student's imitation is acceptable–that is, within preset tolerance–in pitch, for example, the device advances to the next feature, loudness, and the cycle of presentation–evaluation–display is repeated for this feature. Ultimately, the imitation is acceptable with respect to all three features, whereupon the next pattern sentence in the program is presented.

To illustrate the operation of the SAID system we may follow the student through one complete learning cycle. The student, seated in the sound-insulated booth shown in Fig. 4 above, listens to the presentation of the pattern sentence. A light on his indicator panel tells him to imitate the "pitch" contour of the pattern. While he is making his imitation, the meter on his panel is swinging to the right when his response is too high in pitch, and to the left when his response is too low in pitch. In a triad of utterances, for example, two error values are displayed, since there can be no error reading for the first utterance ($S_i = S_o$; $M_i = M_o$). If his largest error indication is greater than the tolerance for accurate imitation, the device will rewind the tape recorder and present the pattern sentence again. Assuming that the student's imitation was acceptable on this second attempt, the device turns on the "loudness" light, rewinds the tape recorder, and again plays the pattern sentence. SAID then repeats the sequence for loudness as for pitch, and for tempo when loudness is acceptably imitated. Finally, the three features must be acceptably imitated concurrently on three successive trials in order for the device to advance the student to the next pattern sentence in the program.

The criteria for accurate imitation have been set at less than 6 per cent error for pitch, 20 per cent error for loudness, and 10 per cent error for tempo. These criteria were selected initially on the bases of acoustic-phonetic research and preliminary experiments with SAID. Ultimately, the choice of criteria must come from systematic listening experiments with native speakers of the target language.

The computer's teleprinter (Fig. 2) keeps a running record of the behavior of SAID and the student. When the cycle begins, the teleprinter types the word "pitch", indicating the feature which the student is trying to imitate. Just before the pattern sentence is played to the student, the teleprinter types the letter "P"; the letter "S" is typed just before the device processes the student's imitation. After the imitation, the result of each comparison of pattern and imitation is typed out. If the student's imitation is acceptable, the teleprinter types the next feature, (in this case "loudness"); it then types the letter "P" for pattern again, and the sequence is repeated. When the imitation is thoroughly acceptable, the student is ready to move on to the next pattern in the program. The teleprinter, then, types out a table of results for all three features for each of the preceding trials before advancing.

A graphic analysis of the learning that has taken place is readily prepared from these records. When pitch, loudness, or tempo differences between the pattern and the imitation are plotted as a function of successive trials, several kinds of trends may be observed; the most obvious is the rate of learning to effect control over the prosodic features. The student's consistency and short-term retention, and the relative difficulty of the prosodic features are also revealed by the plots of error versus trials. We use the term "consistency" to refer to the degree to which the error is steadily reduced prior to reaching criterion, and the term "retention" to refer to the degree to which low-error performance is maintained thereafter.

Preliminary experiments are underway to evaluate the effectiveness of the SAID system in conditioning prosodic accurracy. In one experiment, tape recordings were prepared containing triads of synthetic vowels. Within each triad, the vowel stimuli varied in fundamental frequency, formant frequency, relative intensity, duration or temporal spacing. The error functions for a typical subject are shown for each of the three prosodic features in Figs. 5, 6 and 7. These data were obtained with a pattern of three vowels that varied only in fundamental frequency: 160, 120, and 160 cps. The stimulus duration was 250 msec; inter-stimulus duration was 500 msec; intensity was constant at about 70 db (SPL); the formant frequencies were 300 and 900 cps.

In the plot of pitch error versus successive trials (Fig. 5), the filled squares represent those trials on which the student's error in pitch was displayed to him. The solid line connects error values associated with the change in pitch from the first to the second utterance and the dashed line those associated with the change

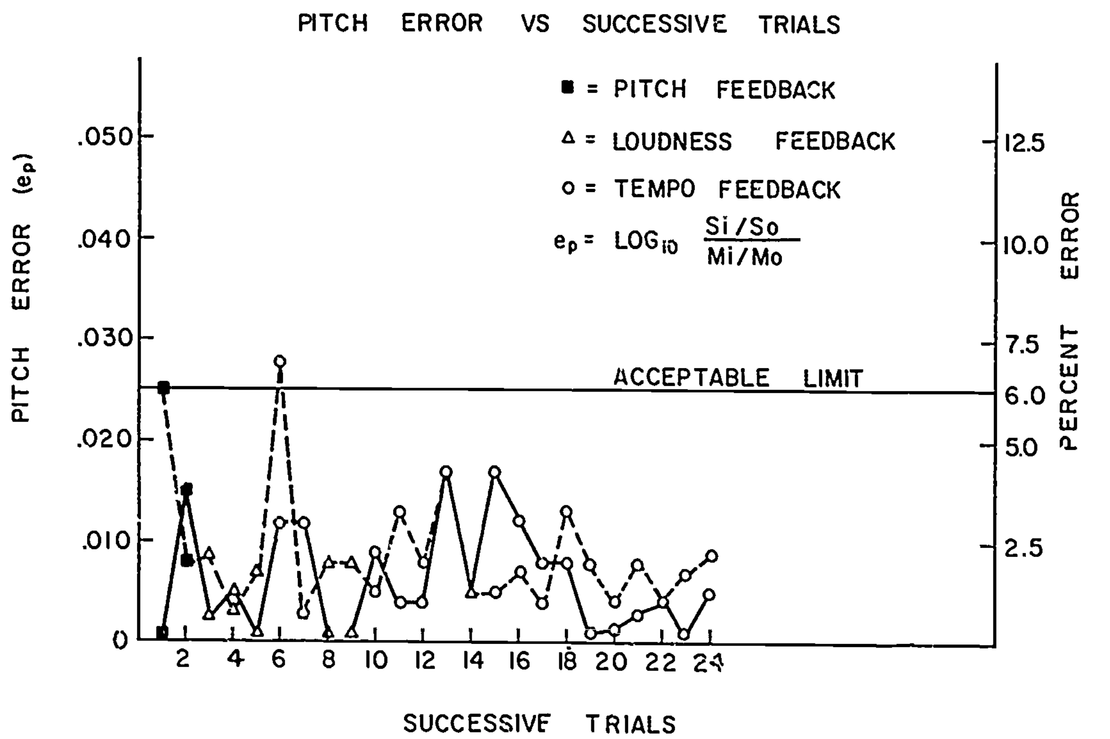

Figure 5. The difference, with respect to changes in pitch, between a triad of vowels, presented aurally, and its imitation on repeated trials by one student.

in pitch from the first to the third utterance. This student, like several others, found the task of imitating the pitch of the vowel pattern quite simple under the supervision of the SAID system. Within a few trials, he achieved and retained a level of accuracy that is well within tolerance.

The SAID system then advanced to loudness evaluation and error display. The student's performance with respect to this prosodic feature is shown in Fig. 6. The filled triangles indicate the error in relative loudness on those trials for which loudness error was displayed to the student. The solid and dashed lines connect normalized error values associated with the second and third loudness values, respectively. Although the student was much less consistent in imitating the loudnesses of the pattern than in imitating its pitch, continued attempts at imitation with visual display of error soon brought the loudness feature of his prosody within the acceptance limits. It is noteworthy that there was an increase in loudness error when the student first turned his attention to imitating loudness. Retention seems to improve with training; the trend of the function approaches a point well within the acceptance limit.

Finally, the SAID system advanced to tempo evaluation and display. The student's performance is shown in Fig. 7, where the filled circles indicate the error in tempo on those trials for which tempo error was displayed. Since there are only two tempo intervals in a triad of utterances, and the first serves as the reference or normalizing value, there is only one reading of tempo error per triad. This student, like several others, was consistent in his imitations of tempo and quickly brought this feature of his prosody within tolerances, but his retention of accurate tempo was poor. The latter finding may be attributable in part to the fact that stimulus duration, inter-stimulus interval, and intensity distribution within each stimulus all may contribute to the perception of tempo. The student whose data are shown in Figs. 5—7 is typical in that tempo was easier to master than loudness, but more difficult to master than pitch.

Inspection of Fig. 7 reveals another programming feature that is presently a part of the SAID system. When the student achieves an acceptable imitation of tempo, the device tests the other two prosodic features concurrently. If the error associated with either feature is greater than criterion, the system recycles to evaluation and error display of the unacceptable feature. If both of the other features are within criterion, a light is flashed on the student's panel. This procedure is repeated until the student accurately imitates all three features on three successive trials. Then, the next pattern in the program is presented.

The capability of the SAID system to provide rapid, reliable and valid evaluations of prosodic accuracy and to adapt the learning sequence in accord with the student's proficiency at each step, as well as the findings of inital experiments with the system, hold promise of improving and accelerating an important facet of second-language learning. These capabilities and findings, however, raise certain preliminary experimental questions that are normally overlooked by traditional methods of language pedagogy. What are the quantitative tolerances

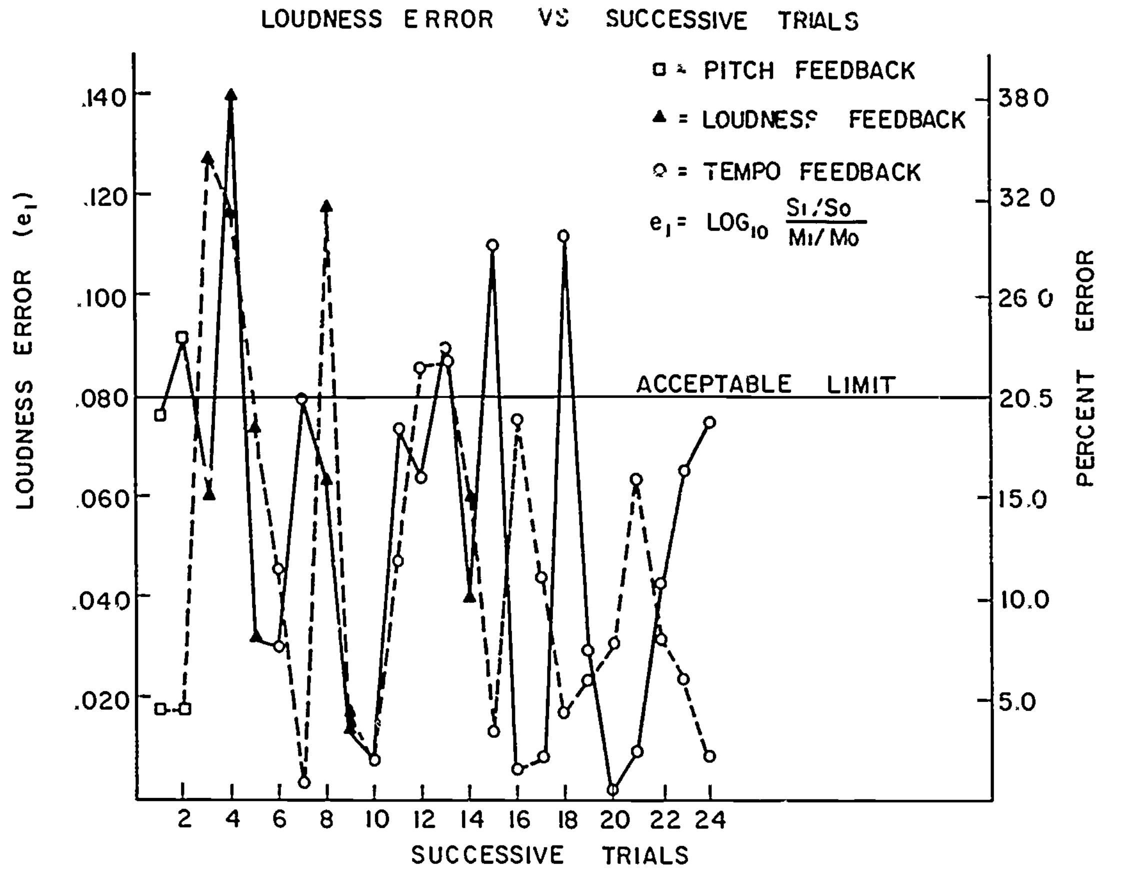

Figure 6. The difference, with respect to changes in loudness, between the triad of vowels and its imitation. The trials are the same as those indicated in Fig. 5.

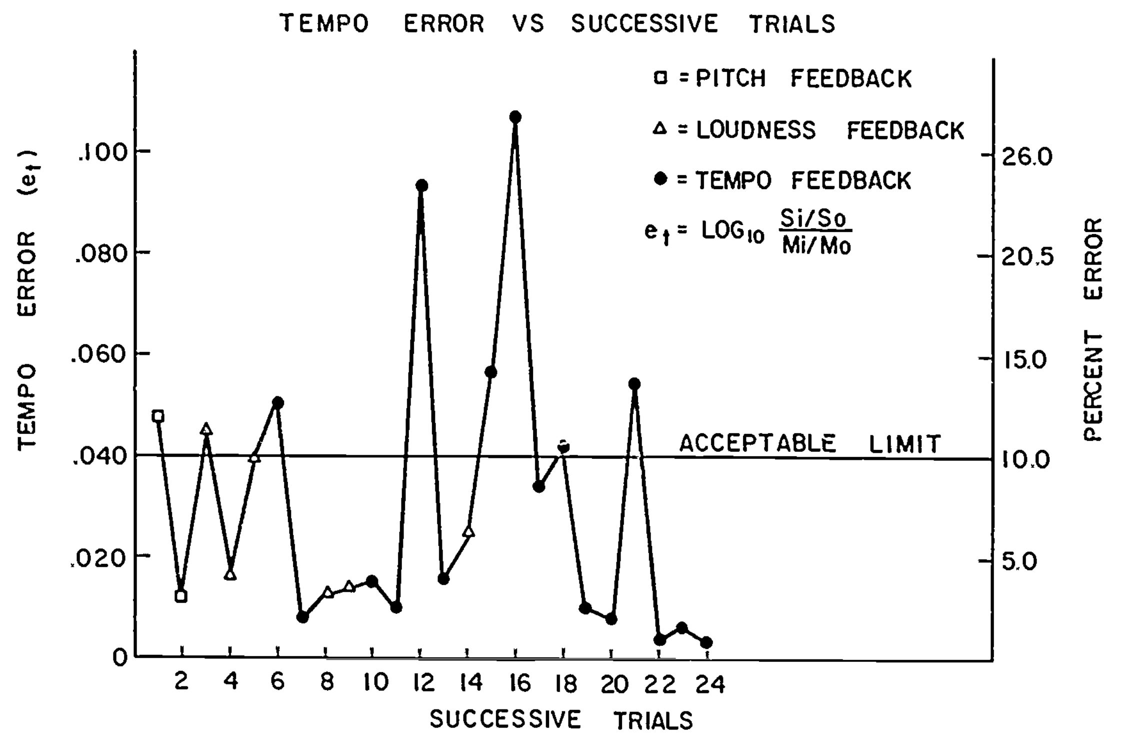

Figure 7. The difference, with respect to changes in tempo, between the triad of vowels and its imitation. The trials are the same as those indicated in Figs. 5 and 6.

of the prosodic features for native-like fluency within a language? What are the sources of facilitation and interference between prosodic skills in a given pair of native and target languages? How well are newly acquired prosodic skills retained outside the learning environment and what can be done to enhance this retention? These and related questions will be examined in future research with the Speech Auto-Instructional Device.

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