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ABSTRACT

RECENT PROGRESS IN SPECIAL PURPOSE TAPE-RECORDING DEVICES FOR LANGUAGE LEARNING ARE DISCUSSED, AND TWO PRELIMINARY EXPERIMENTS IN ENGLISH TEACHING FOR JAPANESE STUDENTS ARE REPORTED ON. BOTH PROGRAMS USE AN UNTRAINED NATIVE SPEAKER AS AN EVALUATOR. ONE IS AN ORAL REPETITION TEST-TRAINING PROGRAM OF SENTENCES. PROBLEMS CONCERNING OPTIMIZATION OF THE TEACHING COURSE FOR INDIVIDUAL STUDENTS ARE DEALT WITH BY USE OF A MULTI-LEVEL STRUCTURE OF THE TEST MATERIAL COMBINED WITH MULTI-DIMENSIONAL EVALUATION MEASURE. FOR THIS PURPOSE, A FEATURE THEORETICAL TREATMENT OF THE PROBLEM IS PROPOSED ALONG WITH A UNIFORM PATTERNIZATION OF BRANCHING STRUCTURES OF THE LOGICAL PLANS FOR THE LESSONS, MAKING PREPARATION OF THE TEACHING MATERIAL QUITE FEASIBLE WITH ASSISTANCE OF AN INTERACTIVE COMPUTER. THE OTHER IS A COMPUTERIZED TEST-TRAINING OF PRONUNCIATION-HEARING, AND SOME TECHNICAL DETAILS BASED ON SOME EXPERIENCE ARE GIVEN. IN BOTH CASES, POSSIBILITIES OF SEMI-AUTOMATIC GROWTH OR IMPROVEMENTS OF THE TEACHING MATERIAL ARE CLAIMED. (AUTHOR/AMM)

TECHNOLOGICAL DEVELOPMENTS FOR LANGUAGE LEARNING*

Osamu Fujimura

1. Introduction --- Problems

Linguistics as the science of language has many applications. Among these we do not need to stress that teaching of foreign languages is a practical problem of ever increasing import, especially as the means of communications substantially change the domain of mutual personal contact throughout the world. In Japan, the situation concerning this point is rather simple and clear to anybody, and is perhaps typical in many respects.

The Japanese language as is well known is an "isolated" language in the sense that there is no other major language that is clearly related to it historically. Comparative studies show that its vocabulary, syntax, and phonology are rather peculiar. Thus Japanese is a difficult language to learn for a native speaker of English, and naturally the reverse is true, too. Tests on English constitute a good part of the entrance examination to a university for Japanese students.

Children in public schools start learning English in the seventh grade of education, usually at the age of twelve. Typically, a school boy takes English lessons in school several hours per week for the three years in junior high school as part of his compulsory education. Another three years may be spent similarly in the senior high school, and then he may take courses again in the first two years of his college life

Even though it is not required that a university student study English, as long as he selects another language such as French, German, or Russian, it is fair to say that a predominant majority of them take English courses as the first and the most familiar foreign language. Out of the national population of about one hundred million, about 5 million are in junior highs, another 5 million in senior highs, and nearly one million are in either universities or short-term colleges where everybody learns English for at least two years. It is estimated that there are 65 thousand teachers in English all over the

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country. In Tokyo, in particular, they live somewhat at a density of one teacher per $(70m)^2$.

Training of English teachers is no less important a problem than teaching so many children. What we really need is not only countable peaks of excellent teachers of English, but almost innumerable common and good teachers for this universal demand in the society. It may be said to be the main point of this paper, that if we try to solve this problem partially by using computers, we then ultimately face a similar interesting problem of how to produce a vast variety of teaching programs, not just how to make one outstanding but isolated masterpiece of computer-aided instruction program.

2. State of the Art --- What can a Machine do?

Let us first clarify our aims and the philosophy underlying them. Current developments in science and technology have brought us to that level of civilization, where an average citizen enjoys a kind of luxury, which even a wealthy king of a few hundred years ago could barely offer to a prominent guest. Who in history could listen to Bach or Bartók at any time of day, even in bed, with an extensive choice of the piece and ensemble whose performers may even be long dead? It is progress in technology that enabled this mass availability of information. Why then should an average citizen not be able to expect to have available a series of personalized English lessons from a recognized authority in the field? It is obvious that present-day technology cannot provide such lessons to everybody now. What can a machine do, then?

The language laboratory naturally comes to one's mind. It may be equipped with a group of tape-recorders, perhaps with some visual display devices, and the recorders can be operated either by the individual students or, whether in group or individually, by the teacher of the class. This perhaps means that he can offer good personalized instructions to any of the students in the class occasionally, without disturbing the other students. This does not guarantee, however, that proceedings of the lesson will be optimal for everybody in the class, unless by coincidence everyone in the class is identical in their characteristics in learning the pertinent subject.

It must be mentioned, however, that it is certainly worth while for the student to have his own tape-recorder. The most important advantage perhaps is being able to control his own pace of learning by use of the prerecorded oral text. In this sense, the language laboratory has the same advantage as any of the recorded language courses on the market. In addition, the magnetic tape-recorders designed for this purpose provide the student with the capability of comparing his utterance with the teacher's.

The main body of the teaching material thus is a linear sequence of prerecorded oral text, or a limited set of them among which a suitable lesson could be selected either by the teacher or by the student.

3. Tape Recording --- Its Essential Limitations and Some Amendments

Communication via sound, including speech and music, can be characterized as an arrangement of codes in a linear sequence in the time domain. Magnetic tape recording is a wonderful technique for storing and retrieving messages in their natural sequence. It has a serious weak point, however, which becomes apparent when one attempts to deviate from the natural and preset time flow. A look-up of a particular subject in recorded radio news, for example, is just impractical in contrast with the ease of locating it in the case of newspapers.

This disadvantage of tape recording can be circumvented to various degrees by some additional techniques. There are two moderate but nevertheless important modifications of regular tape-recorders for special purpose language self-teaching or language laboratory devices. One is a multi-channel scheme often accompanied by the use of a larger width and shorter length of tape. A typical example in the market has performance specifications as follows:

tape width	12.7mm
number of channels	12 (playback only) + 2 (record--playback), one of which can be mixed with the prerecorded signal on one of the other 13 channels on playback
tape length	92 m
tape speed	9.5 cm/sec.

frequency range 100 - 8,000 Hz

signal to noise ratio ≥ 40 dB

This partial "two-dimensionalization" of tape, which certainly is physically semi-two-dimensional, makes it possible to store the text of one lesson on one track of the tape, selection of a lesson among a dozen being done by a manual switch. To allow for lessons supplementary to the main set of pre-recorded (and unerasable) lessons, the machine mentioned above also has two additional recordable tracks. One of them can be used for storing individualized or temporary oral text, typically given by the teacher in a language laboratory or perhaps in the future through a telephone connection to a teaching center. The second recordable track is used for recording the student's utterances for his own comparison with the recorded text (either in the main lesson or the supplemental lesson).

The second innovation, which is technically rather trivial but none the less important in view of the general considerations mentioned above, is a "repeat" scheme. By pressing a button for this mode of operation, the tape runs in reverse at a speed less than the usual reverse mode with the reversed speech played audibly. When the push-button is released, the tape stops there. Thus a stretch of speech, typically a short sentence or a clause, can be identified and the tape can be brought back to the pause position preceding it for a repeated listening. There is even a fully automated version of this scheme which is technically very ingeniously designed. One make of such special tape-recorders employs a servo-motor, which in this particular reverse mode is powered by the amplified speech signal itself. When the nearest pause comes in the reverse direction, the tape stops automatically.

It is probably obvious to those who have some experience in teaching themselves a foreign language via a pre-recorded oral text, that the repeat mode, though it seems simple in function, is a very crucial modification of the playback system for the purpose. If the texts are prepared with much experience and knowledge as well as care for the students, the self-teaching devices presently available are quite worth the price; in other words, the cost of the hardware device is not too significant compared to the cost of preparing the teaching material itself.

For our experiment in our laboratory which will be described in the next section, however, we needed a more specialized system. We modified a double-track regular tape-recorder for implementing a mode of automatic skip in both forward and reverse directions. One of the channels is used for recording pulses as cues for selection of the stop position. This cue can be sensed while running the tape at a high speed, and a logical circuit can be preprogrammed to select the desired cue to the tape. The cues have to be prerecorded as well as the utterances, and there are some technical details and some possible elaborations which I am not going to deal with here.

4. An Example - Sentence Repetition Test

The skipping mode, though it may seem very simple in function, provides us with the option of substantially deviating from the linearly ordered fixed program of teaching or testing. By adding a pulse counter circuit to append it with, we can skip any number of samples at a time according to some decision made on the spot. We can then sophisticate the logic of selection of the test items to a high degree of complexity provided that we are equipped with appropriate logical assistance to write interesting teaching programs. There are of course some practical considerations that limit the power of such a machine for use in language teaching, e. g., we have a trading relation between the cost of equipment and the amount of time we can allow to the system for fetching the next sample on the tape.

Just to explore the situation we once ran an experiment of a very preliminary nature. As a practical case of particular interest, let us consider a test-training session where the student is supposed to repeat what he hears. Some other variations in his task can be treated similarly by rather obvious generalizations. A short text was written by James D. McCawley for this experiment when he was in Tokyo in the summer 1967. Several students in the level of high school students participated in the experimental teaching course. A session was prepared for the students every week and some text consisting of a story on a subject and explanations were given to them as homework. At the end of the week, each student sat for an individual test session. A special tape recorder ran the tape prepared for the test, essentially in the manner described above, though the sample selecting operation was simulated at that time by a human operator in place of a computer program. A test session consisted of many items, each prepared in the form of a "page." Each page contained a set of several sentences with some special directions, for proceeding to the next presentation of one of the prerecorded sentences. The following chart shows a typical page from this test (cf. Chart 1).

When the student repeats the sentence reproduced, a native speaker of English, who may be called an "evaluator", evaluates the student's performance, in this case by a dichotomous scale: good or poor. When this evaluation is given, by typing on a keyboard or by a special switch, the prescribed logic automatically determines the choice of the next sentence. The logic is given at the right of the page in the chart above for the sample page. Thus if the response to the first sentence was poor (see 1. a in the chart), the short vertical arrow indicates that the next lower box for the sentence reproduction must be chosen, viz., repetition of the same sentence (1. b). If the evaluation there is good, the horizontal arrow indicates that the student can proceed to the top of the next page. If it is poor, on the other hand, he proceeds to the next lower row (2. a) of the same page where there is a more elementary sentence. He proceeds in this way to more complex sentences in the succeeding lines until the originally presented sentence is tried again.

This program is designed in such a way that a rudimentary tape-recorder can be used without much complexity in the way of real-time logic for the selection of the next sentence, by skipping, at most, a small number of sentences in the forward direction. The logic was indeed simple and straightforward: First try only the complete form for each page. If it is done well, go to the next page. If it is done poorly, go to the most simplified form first and try to gradually recover in complexity. The student is allowed to listen to the same sentence twice if necessary, but if he still fails to perform well, he has to give up and go to the next page in any case.

Chart 1 Sentence Repetition Test (page 83, McCawley)

OK NO

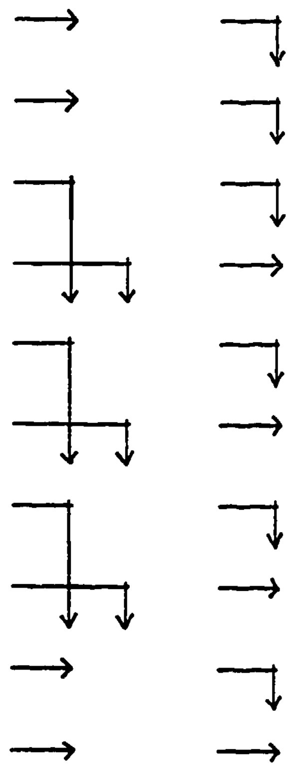
line 1. Why don't we go and have a look at the fountain in Grant Park? (a) (b)

2. Why don't we look at the fountain? (a) (b)

3. Why don't we have a look at the fountain? (a) (b)

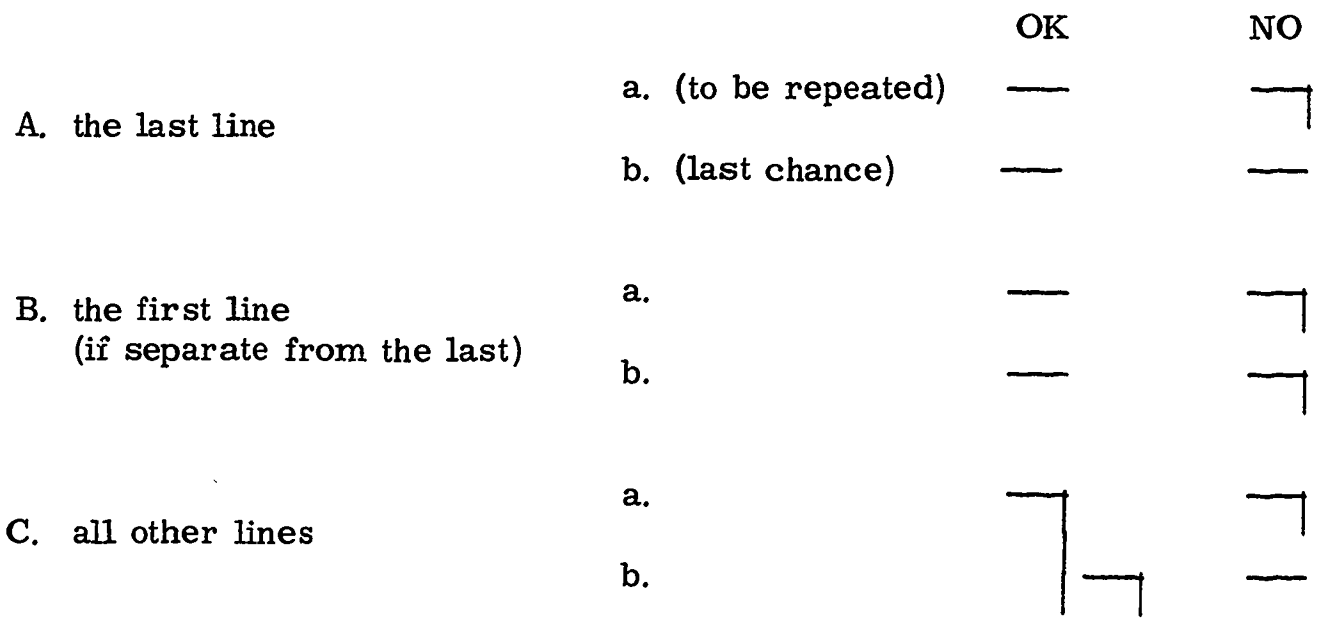
4. Why don't we go and have a look at the fountain? (a) (b)

5. Why don't we go and have a look at the fountain in Grant Park? (a) (b)



We later analyzed the actual test material prepared by McCawley for this experiment. This analysis was done on about 70 pages of the last test session, in which the material was better prepared reflecting the experience gained from preceding sessions. There were to be six different patterns a page could take in terms of the proceeding directions (cf. Chart 2). All of the cases are uniform in the structure except one case (case IB) which had an amusing kind of instruction which anyway could not be followed by the hardware device we had at the time. * Thus quite generally, as far as the material prepared here is concerned, we can state the instruction patterns in one universal format like that in Chart 3.

Chart 3 Elementary Structures of Sentence Repetition Format



For the last line, there is no other choice in this simple scheme (see <u>infra</u>) than to go to the next problem (i. e. the next page) except a possible repetition of that line (presentation 5(b) on Chart 1). The first line is always the full form. If the student fails, but if there is any more elementary version of the sentence, he should not give up on the page but go to the next line if he fails. In case of failure on the intermediate lines, no choice other than giving up with the page can be prepared, beyond simple repetition, since the

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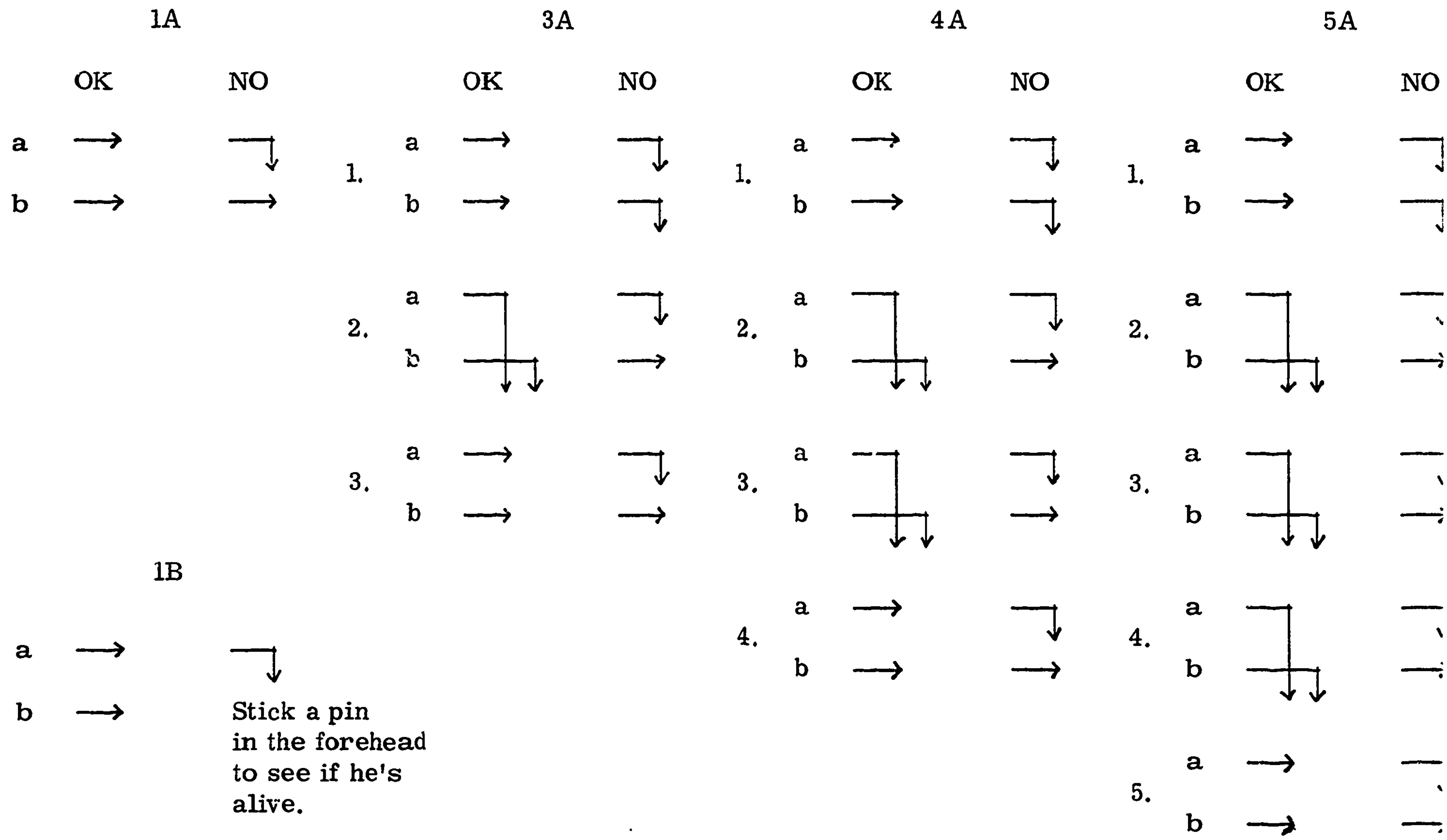
* Actually another case was found which is not shown in Chart 2, but this could readily be reformulated in the regular pattern simply by changing the instruction pattern. In fact, there is found no particular reason why this should not be so.

Chart 2



1A
OK
NO
a
b
1B
a
b
Stick a pin in the forehead to see if he's alive.
3A
OK
NO
1.
2.
3.
a
b
4A
OK
NO
1.
2.
3.
4.
a
b
5A
OK
NO
1.
2.
3.
4.
5.
a
b

elementary sentences were considered as prerequistite for possible success in the more complex form.

Now that we see enough uniformity in the format of writing the test material, we can automatize quite a significant portion of the task of both writing the problems and performing the test. The job of writing and recording the test material in the full form is very time consuming and susceptible to errors. Since we already know the regularity of the structural pattern explicitly as formulated in Chart 3, all that the writer must specify, e. g. , for the page given in Chart 1, is the following information:

Chart 4 Repetition Test Formulator, Input Format

Page 89

1: Why don't we go and have a look at the fountain in Grant Park?/

2: Why don't we look at the fountain?/

3: Why don't we have a look at the fountain?/

4: Why don't we go and have a look at the fountain?/

5: = 1

We can write a special computer program (repetition test formulator) for the functions given in Chart 5.

When we disregard the full form as the first sample to be presented for the "page", we generally have patterns of growth from the more elementary to the more complex. In the content of Chart 4, for example, we readily notice an analysis such as the following.

Chart 6

Why don't we	go	and	have a look	at the fountain	in Grant Park	?
A-	B	C	D, D' = look	E	F	-A/

This analysis may be reformulated as the following chart for inputting into the machine through a regular typewriter. Present day technology in

Chart 5 Repetition Test Formulator

Part A: Text Writing

1. The machine types out the underlined items of Chart 4, line by line. It starts with "Page."

2. The writer types in the page number.

3. The machine types "1:" and waits.

2. The writer types in the sentence for the line and slush.

3. The machine carriage returns and types the next item number, and the process above is repeated.

4. The writer finishes the page by typing "= 1."

5. The machine asks for the next page number.

6. Repeat the process for pages. At a certain point, finish the series of problems by typing "end" after "page."

Part B: Recording Oral Text

1. The machine types out the sentence for each line.

2. The talker reads and utters the sentence.

3. The utterance is recorded in the computer controlled special analog-digital tape-recorder, with digital information including the written text and the associated operation specifiers (A, B or C in Chart 3) as the digital labels attached to the sentence (line).

interactive use of computers provides us with a means to do the job faster and in the more intuitively appealing form of Chart 6, directly by manipulating an oscilloscope display with a lightpen. Namely, the man types in the full form (line 1) and the machine displays it on the oscilloscope. The man underlines "Why don't we" by the light pen and types "A-." For a modified phrase, he types in the primed symbol and defines it by an equal sign. Then he types in the lines in the upper half of Chart 7 in order to specify the structure. That's all for the page and the rest is taken care of by the machine except for the speech recording session as described above (Part B of

Chart 5).

Chart 7

2. A (D' E)
3. A (D E)
4. A (B C D E)
5. A (B C D E F)

A = Why don't we (   )?
B = go
C = and
D = have a look
D' = look
E = at the fountain
F = in Grant Park

5. Branching and Features

Let us now consider the organization of succeeding pages. Chart 8 is an excerpt from the Test, where only the first line (i. e., the full form) is shown for each page in one lesson. Obviously, we wish to construct the entire session in such a way that it has some semantic contextual continuity. In the case of the experiment mentioned above, the student had been given a written text for his homework to work on for a week before he came to take the test. The homework text contained stories on some subjects and had some grammatical explanations. Even though it is a test that he takes, we still wish to place him in a somewhat realistic situation, so that his semantic faculty functions in the normal mode of language behavior. We also wish to retain his interest. In this way he can also learn and make progress during the test. At the same time, however, we have to take into consideration the fact that students are different from each other; they do not perform equally well. If we try to let a student do things too difficult for him, he simply gets discouraged. On the other hand, if he has to go through easier tasks all the time, a good student gets bored, and also it takes too much time and consequently is unduely costly.

In the case of the McCawley test, we had many compromises because of the limitations in hardware implementation. The format of a page, as described above, started always with the most complex form. Thus occasionally we would find that frequent appearances of these full forms had no effect other than discouraging the student. In order to remedy this situation, we had means to change the course of the test. The overall structure of the test course in one lesson, with some simplifications of irrelevant technical details, is given in Chart 9. As we can see in this flow chart, an overall success (the judgment "good") on the series of pages (subsection) I_o

Chart 8 First Lines of Succeeding Pages in One Lesson McCawley Test

I^{o} 1. Does your brother play the guitar?

2. Yes, he does.

3. Is he playing the guitar right now?

4. No, he isn't.

5. Right now he's listening to the radio.

6. Does he listen to the radio a lot?

7. No, he hardly ever listens to the radio.

I^{o}_{a} 8. Is your brother listening to the radio?

9. No, he isn't.

10. Well, what is he doing?

11. He's playing the guitar.

I^{o}_{b} 12. Does George play the guitar a lot?

13. Yes, he does.

14. He plays the guitar every day.

15. Do you play the guitar?

16. Yes, I do.

17. But I don't play it very often.

18. As a matter of fact, I hardly ever play the guitar.

19. *

I^{+} 20. Does your brother eat ravioli often?

21. No, he hardly ever eats ravioli.

22. *

23. *

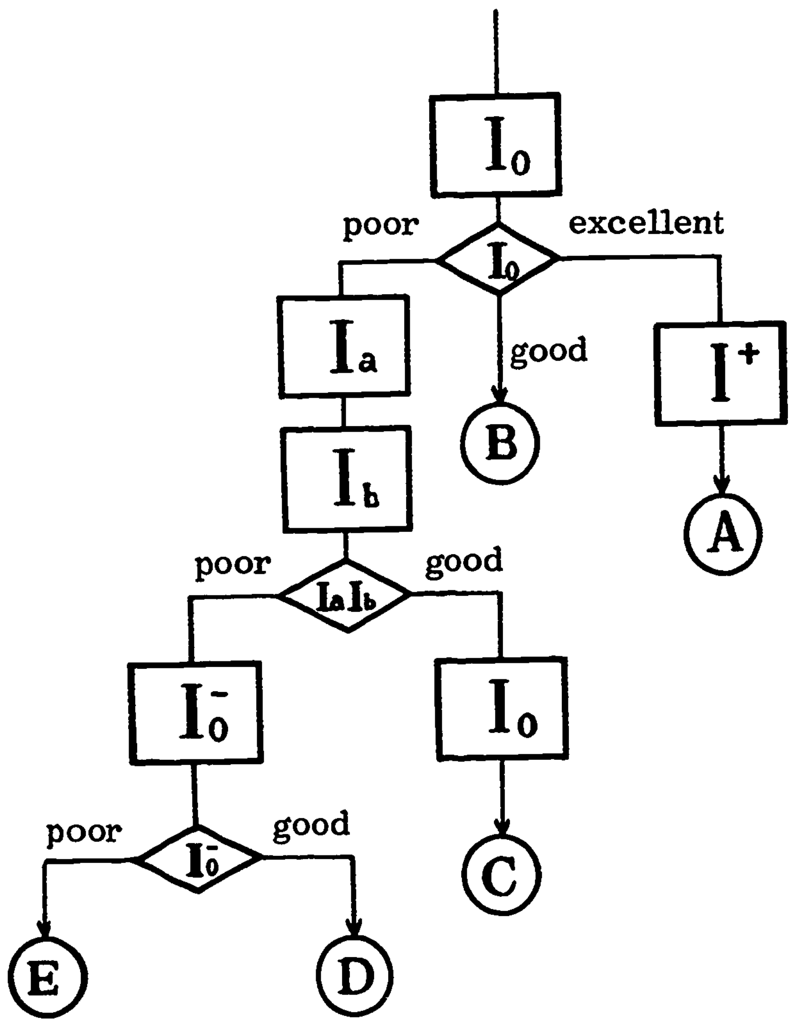
24. =1.

.

.

30. =7.

Chart 9 Flow of Test in the lesson (McCawley Test)



leads the student to the next subsection of the lesson where a different topic is treated in a similar schedule. When the student is particularly good, the path "excellent" leads to a special subsection I^+ and completes the course of learning contained in this lesson. If the student is poor on I_o, he then receives supplemental pages in subsections I_a and I_b. If he gains enough in these supplemental courses, he has another chance to try the main subsection I_o. If not, he enters a leveled-down subsection I_o^-. The overall judgment for a subsection can be calculated from the paths the student has taken in the pages contained in the subsection.

The subsection I_o^- consists of the same pages as in I_o, but skipping the first line, viz., the most complex form in each page. The path he takes then will certainly be better suited to him. But whichever path the student takes and regardless of the consequent node he arrives at, he proceeds to the same entrance to the next lesson in this preliminary experiment. This is not desirable, since in determining the course in the next lesson we thus ignore the information already obtained by the preceding test on the particular student. The states A, B, C. D. and E in Chart 9 respectively represent the student's characteristics, and his graded record of performance in the test. The content of the next lesson could be "tailored" to his individual level, depending on whether he had obtained e. g. A (excellent), B(good) or E(the poorest and totally disqualified for a similar course at the same level in any subject).

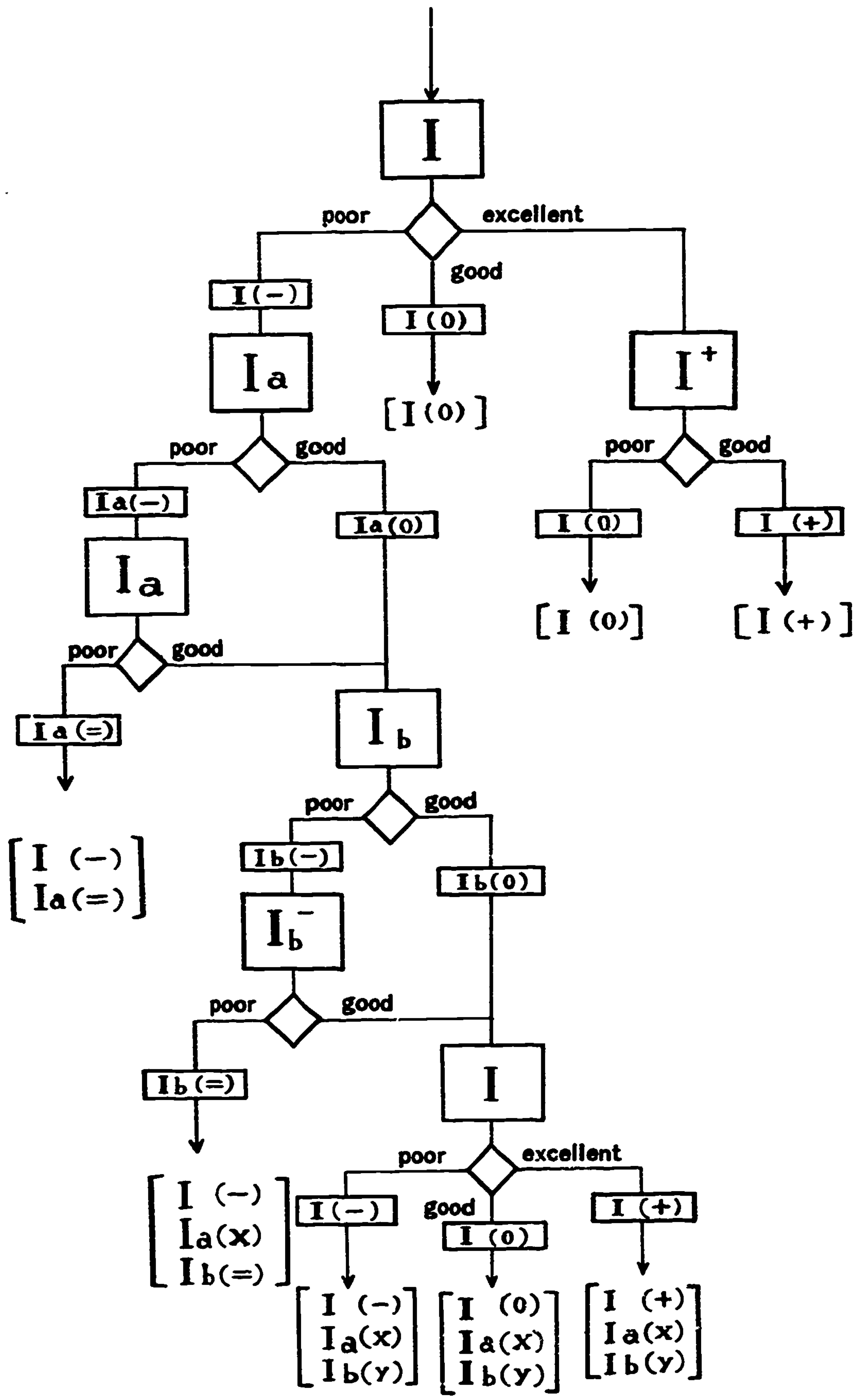
Upon inspection of the content (see Chart 8), it is readily seen that there are two kinds of syntactic forms used, which are the main (grammatical) points of this lesson. It is the use of the present nonprogressive vs. the present progressive and the special adverbials associated with these forms. The supplemental materials I_a and I_b are meant to give the student a chance to recall what he has already learned somewhere else and consolidate the knowledge for its actual use. Since this type of test structure will be frequently used for treating similar grammatical problems, we should try to find some framework for adequately handling them.

A possible treatment of such cases is shown in Chart 10. It must be first noted that a mere branching as in a finite automaton (or a CF-grammar for this matter) is not adequate, because we would like to retain information about the evaluation in one aspect in parallel with that for another. The most useful notion here is probably the decomposition of the state into a set of features. A student who is deficient in mastering the progressive mode must be marked as such in the form of a feature statement Ia(-1), so that he may be given special treatment on this point when we select further courses for him in the test-training sessions and also when we assign him some individualized homework.

The structure of text as shown in Chart 10 may appear quite complex, but the regularity of the sub-structures therein allows us a good deal of automatization in preparation of such material. In fact, what the writer must specify to the computer via a formulator program, which may have specifications similar to the example given in Chart 5, is essentially the content given in Chart 7 (the lower half being replaced by Chart 6) for each line of Chart 8, just as before. The logical flow of the session, under some generalization of the program allowing necessary flexibilities, can be entirely taken care of by a general test formulator program.

By giving evaluations of the student at the end of each lesson, detailed with different features as required, we can organize the overall structure of the test-training course comprised of many lessons in such a way that

Chart 10 Flow Chart (Sentence Repetition)

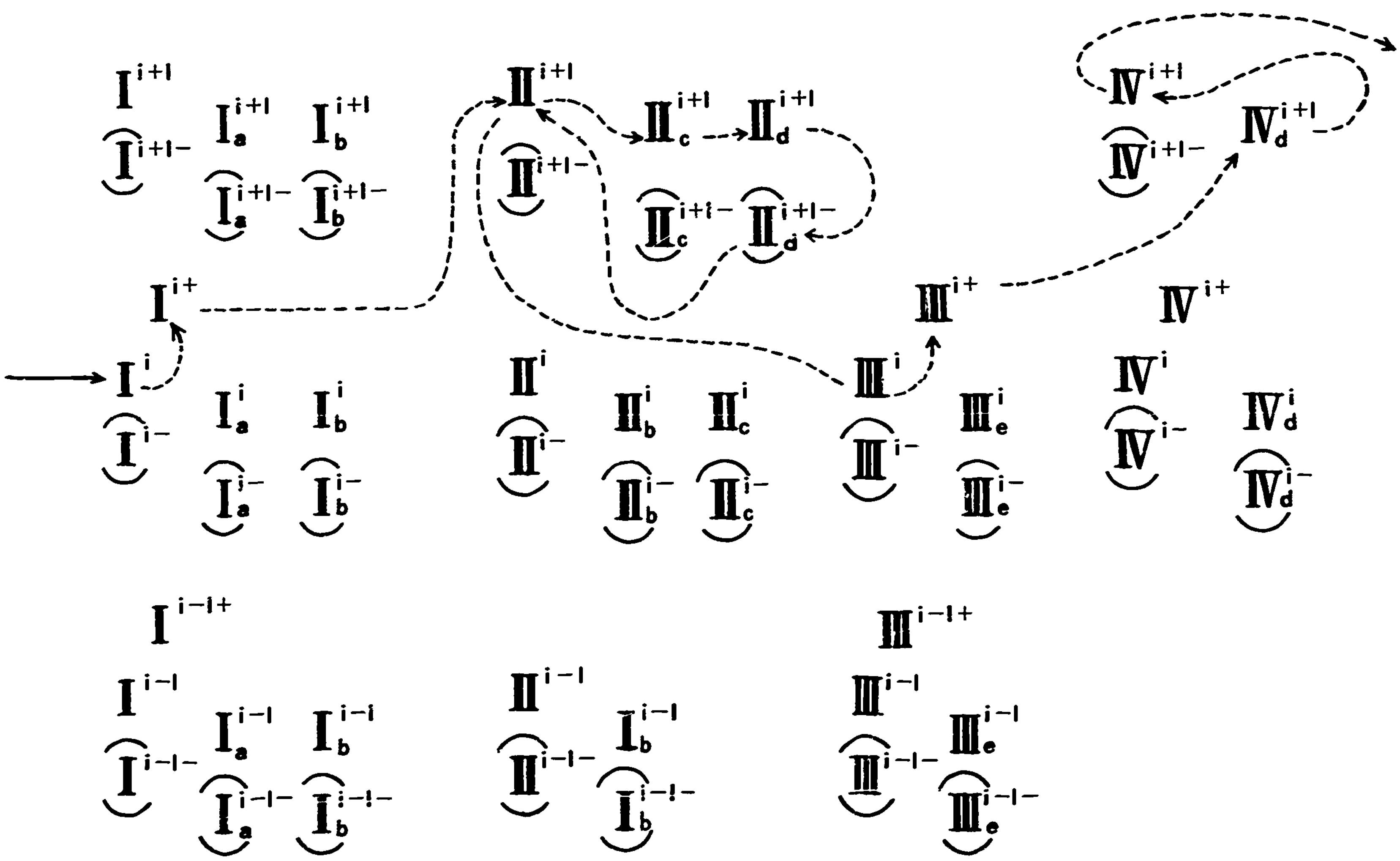


the next lesson will be for him of the level most appropriate for progress in a multi-dimensional measure considering different features. For this it is presupposed that we have lessons in different levels treating similar content, semantically, syntactically, and lexically. A design of such an overall scheme may be proposed as in Chart 11. The dotted line in the chart shows one of the typical paths a student might take. It is seen that the student's record in some particular features along with his overall performance level carries over across lesson boundaries in order to make it possible to enter at the appropriate point of a later session considering his characteristics concerning the same feature contained in the different topic.

It must be mentioned here that the characteristics of a student is represented by the pattern of transition from lesson to lesson. This would be recorded in the form of a feature complex like $[\ I^{i}(+)/II^{i+1}(-)/II_{c}^{i+1}(0)/ II_{d}^{i+1}(-)/II^{i+1}(0)/III^{i}(+)/IV_{d}^{i+1}(0)/IV^{i+1}(0)----\ ]$ in the case of the path given in Chart 11, for example. If there is a peak or a dip in terms of the level of this transition path, we can say that he does better or worse on a particular feature in view of the average level of progress, and accordingly we can provide him with some supplementary training. If an uneven jump at a particular lesson characterizes not only a particular individual but most of the students in a group in the same way, then we can conclude that the design of the teaching material is not well organized in this respect at least for this group of students. The actual run of the program would thus point out the defect of the program so that the assignment of levels in the program can be readjusted semi-automatically or some new material can be added to improve the program. This self-improving capability is of particular interest when we consider practical problems of writing an extensive set of "self-adjusting" teaching programs.

One more point of interest is the implications of the analysis of sentences into components as shown in Chart 7 (or 6). This gives some approximate measure for automatic evaluation of semantic and syntactic correlations between the content of different sessions. It also makes it

Chart 11



possible to equip the text writer with some automatic assistance for writing teaching materials by giving him an effective automatic editing and retrieving service by mechanical means. This is a very challenging topic, but we are not in the position to go into concrete details here.

6. A Computer Controlled Tape Recorder

So far we have discussed a repetition test as a representative example of the overall training of a non-native language. Only the very early stages of an experimental scheme have been actually implemented and tested. But all the structures of the text discussed above are technically feasible to handle by the existing hardware devices for oral tests with pre-recorded speech as the test material.

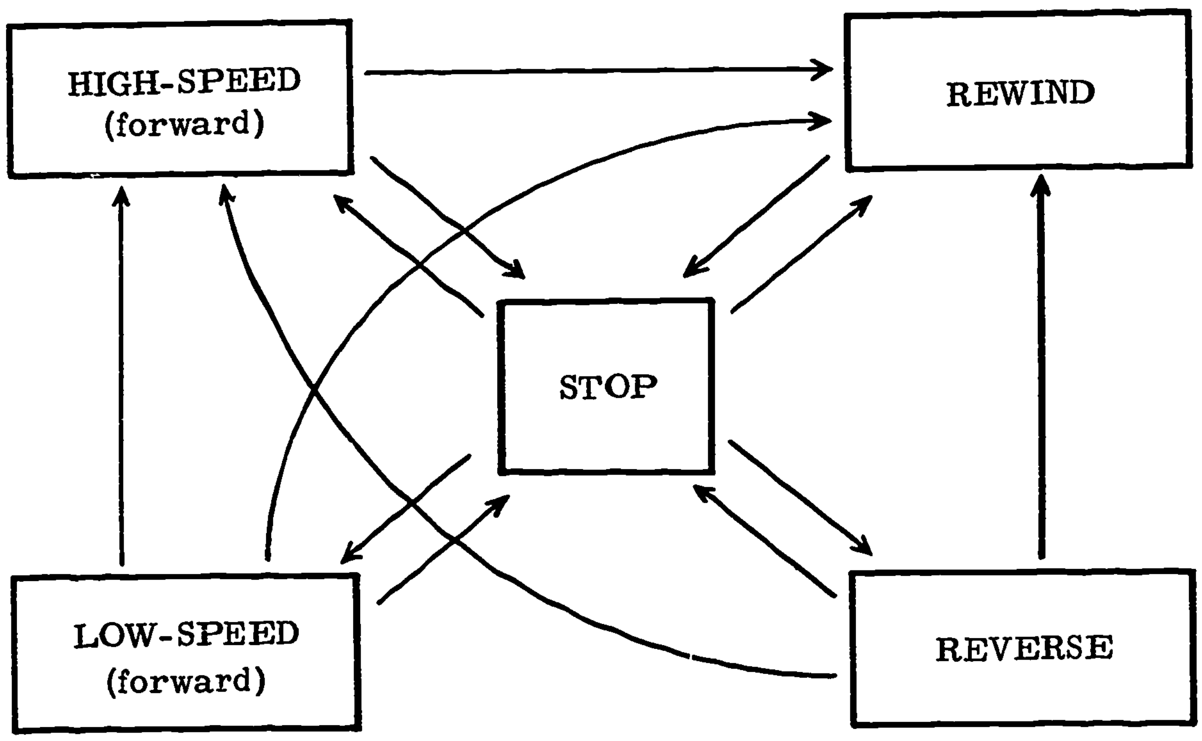
For preliminary experiments of such test-training courses, we devised a simple but special tape-recorder for on-line computer control with rather modest technical specifications. It is a hybrid tape-recorder in the sense that it records and reproduces both analog speech signal and digital codes. There is one analog track and five digital tracks on half-inch wide tape. The digital codes can be recorded and reproduced in the high speed mode, as well as in the slow speed mode which is the correct speed for the speech signal. The technical specifications for the mechanical tape driving system are given in Chart 12. All controls are given by the computer (DEC, PDP-9). A faster mode of rewinding is also provided for changing the tape reel, which can accomodate 1200 feet of tape, 40 min. worth of speech material.

The format of recording the speech and digital codes(i. e. labels) on the tape is exemplified in Chart 13. While the speech sample S(i) is being played in the low speed or silently passed in the high speed, the label for the next word is read into the computer. If it is in the high speed, the digital information is processed and a decision is made whether the next sample should be skipped again, while the tape is running. If so, the tape continues to run in the high speed. If the next label is the one being looked for, the tape stops at the boundary mark (the dots in the figure) and then runs at slow speed to play the next speech signal. If the tape is being played while

Chart 12 Mechanical Specification of the Hybrid Tape Unit

	tape speed	direction	digital read/write	audio record/play
High Speed	75 cm/sec	forward/reverse	200 BPI (5 tracks)	---------
Low Speed	15 cm/sec	forward only	200 BPI (5 tracks)	(1 track)

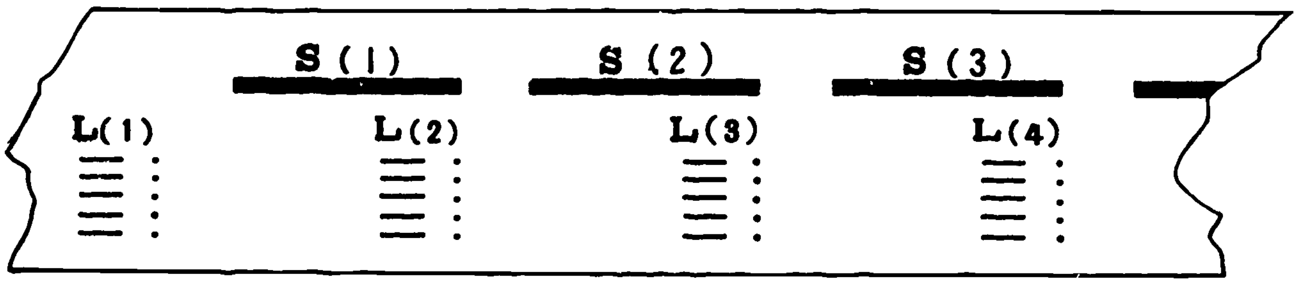
Transition Diagram



the next digital label is being read, then digital information is stored in the computer memory, the tape stops at the boundary mark, and awaits for the student's response and the resulting evaluation. When the tape is running in the reverse mode looking for a particular label, it stops immediately after having completed reading the right label in reverse derection, backs up in the slow speed, opens the speech gate at the boundary mark and start playing the speech sample.

The actual process of preparing such a hybrid tape is somewhat

Chart 13 Hybrid Tape Format



S (i): the i-th speech sample on analog track

L (i): label for the i-th item on digital tracks

complex, but the complexity can be entirely taken care of by appropriate computer programming. All the man has to do is to record the speech sample one by one, and type in the appropriate label or read it in by pre-punched paper tape and identify it by automatic type-out.

7. Pronunciation - Hearing Test

The computer-controlled hybrid magnetic tape system described above was used in a pilot experimentation of another test-training program designed for Japanese students, and involving the pronunciation and hearing of English. An earlier version of this program was originally written by Miss Sue Hanauer in cooperation with us when she was in Tokyo supported by the Tec Corp. on leave from Bell Telephone Laboratories. The program which will be described here is a modified version, and it is meant to be improved and elaborated via actual test sessions.

There are three different student's tasks from which we can select one for actual use in the program.

1) oral repetition of presented speech
2) pronunciation of typewritten word
3) spelling (type in) of presented speech

In the first case of these tasks, the machine plays the spoken word and the student is supposed to repeat it. The evaluator, a native speaker, judges according to some predetermined standard whether it is OK or NO, and types in the judgment. Accordingly, the machine selects an appropriate word by running the tape until it finds a word that is appropriate for the present set of states of the student, and plays the word. In general, the machine skips a test word if it is predicted as either too easy or too difficult for the student, by the algorithm given below. By adopting this version of the student's task, we test (and train) the student's overall proficiency including both hearing and pronunciation.

The second case tests only his pronunciation. Some problems may exist in interpretation when he has difficulty in obtaining the sound shape of an unfamiliar word from the orthography. On the other hand if we use phonetic transcription of some kind, the test may not be usable by all students. A compromise is to use a sort of rationalized orthography or pseudophonological spellings. A native speaker again will make the evaluation. Since a special tape recorder is not necessary, this mode of testing is suited to any computer laboratory, particularly for preliminary studies of automated testing systems.

The third mode can be adopted without having a human evaluator, and it tests only the hearing capability of the student. A criterion can be set for judgment of agreement between the student's answer and the "correct" transcription, depending on which kind of transcription system we adopt. This judgment can be given either by the machine, if the criterion is appropriately formulated, or by the student himself in informal self-teaching sessions. In the latter case, no assistance is necessary besides the computer system.

The present program is designed in the following form. A word in its sound shape is defined as

$$\text{Word}=C_i V C_f,$$

where for the initial consonant cluster

$$C_i=\text{P-, SK-, STR-, H-, KW-, DJ-, etc.}$$

and for the final consonant cluster

$$C_f=\text{-D, -NT, -KST, -FTHS, etc.}$$

and for the syllable nucleus

V=AE [æ], AJ[aı], IJ[ij], OW [ou], etc.

The symbols are pseudophonetic, or allophonic, let us say, with some peculiarities particularly in the correspondence between a symbol and a segment (of whichever kind). In the first approximation when we begin to prepare the material, we treat each C_i, C_f, or V as an independent "word feature" (WF) which is unrelated to others. Thus P- is not related to SP- nor to -P. We will later introduce the notion of correlations between word features in terms of their elementary features as components of WF's, and will try to define and evaluate the correlations by empirical results. Similar heuristic principles work in other points of the experiment, like the definitions of WF-levels as given below.

To each WF is assigned the following properties:
(a) WF-number, (b) phonetic representation, (c) WF-level. The last property is tentatively defined by assigning to each WF an integer (between 1 and 6 in the initial form of the program), which is supposed to represent the inherent difficulty of the WF (the higher the digit, the more difficult). These WF-level values may be considered as parameters that stay constant during a session or a series of sessions. Each WF, in addition, has variable values of WF-state and WF-count during the session. The WF-state varies and represents in the form of an integer the current record of the student's performance in handling this WF, and the WF-count simply represents the count of the WF in test words so far tried by the student in the test. These variables of word features as stored in the computer memory during the course of the test may read as in Chart 14. There are 62 WF's for C_i, 181 for C_f, and 15 for V. "Word-level" is defined as the maximum of the WF-levels of all the three WF's contained in the word. Thus e. g. the word "widths" which belongs to the Level 6 is analysed as in Chart 15. A test consists of a series of sections of increasing levels, with a section at any given level (Section-level) containing only words of the same Word-level.

The assumption is that a student of a Section-level i would be performing well on words that do not contain any WF of a WF-level higher than i, thus proceeding through all the sections up to section i without difficulty.

Chart 14 Word Features and their Variables

Word Feature (WF) (*: parameter; #: variable)

Number	Symbol	WF-level*	WF-state#	WF-count#
1	I	5	0	0
2	E	1	9	38
3	AE	4	-3	5
.	.	.	.	.
39	SF-	4	3	8
.	.	.	.	.
103	-SK	3	2	3
.	.	.	.	.
238	-TTHS	6	0	0

Chart 15 Word Levels

ex. Widths =	W-,	I,	-DTHS
WF-levels	3	5	6
max. WF-level			↑
Word level = 6			

This, of course, could not be the case all the time, and deviations from this prediction gives us information about the particular student and also about the validity of our assumption and parameter settings (e. g. assignments of levels to WF's).

For the purpose of preparing ordered word samples as the test material, we looked for as many combinations of WF's as possible in existing English words and made a catalogue of these words. In preparation of this extensive catalogue, Sue Hanauer, a native speaker of General American, relied on the Kenyon-Knott Pronunciation Dictionary and generally adopted the first variant pronunciation given for the word.

In order to meet the design of the program, we selected about 2500 words out of the catalogue and ordered them according to the Word-levels. An excerpt of a word list thus obtained is given in Chart 16 in the form of information stored in the computer memory during the test. The last

Chart 16 List of Words

Level 1	K-IJ	1-1	K-/IJ
	N-E-K	1-1-1	N-/E/-K
Level 2	SP-IJ-D	2-1-1	SP-
	SK-UW-P	2-2-1	SK-/UW
	KY-UW-B	2-2-2	KY-/UW/-B
Level 3	S-E-LF	2-1-3	-LF
Level 5	D-E-THS	1-1-5	THS
	SPL-AE-SJ	5-4-3	SPL
Level 6	W-I-DTHS	3-5-6	DTHS

column of this chart lists the WFs of the maximum level, which is equal to the pertinent Section-level. Care is taken also within each section about the ordering of the word samples. Thus the three digits representing WF-levels of each word are rearranged so that a higher digit is always placed to the left of a lower digit, and a three place digit is composed in this way (Chart 17). Then the order of words is given in such a way that the series of these three place numbers monotonically increases as the magnetic tape proceeds. The tape contains the series of words, supposedly in the increasing order of difficulty, with boundaries marking changes of the sections, and according to Word-levels.

Chart 17 Word Ordering

K-IJ	1-1	110
N-E-K	1-1-1	111
G-UW-S	1-2-1	211
T-OA-K	1-3-1	311
GL-E-RZ	3-1-2	321
S-OA-RT	2-3-2	322
T-OW-LD	1-3-3	331
SL-AJ-ST	3-3-3	333

A flow chart of the test-training program is given in Chart 18. As the

Chart 18

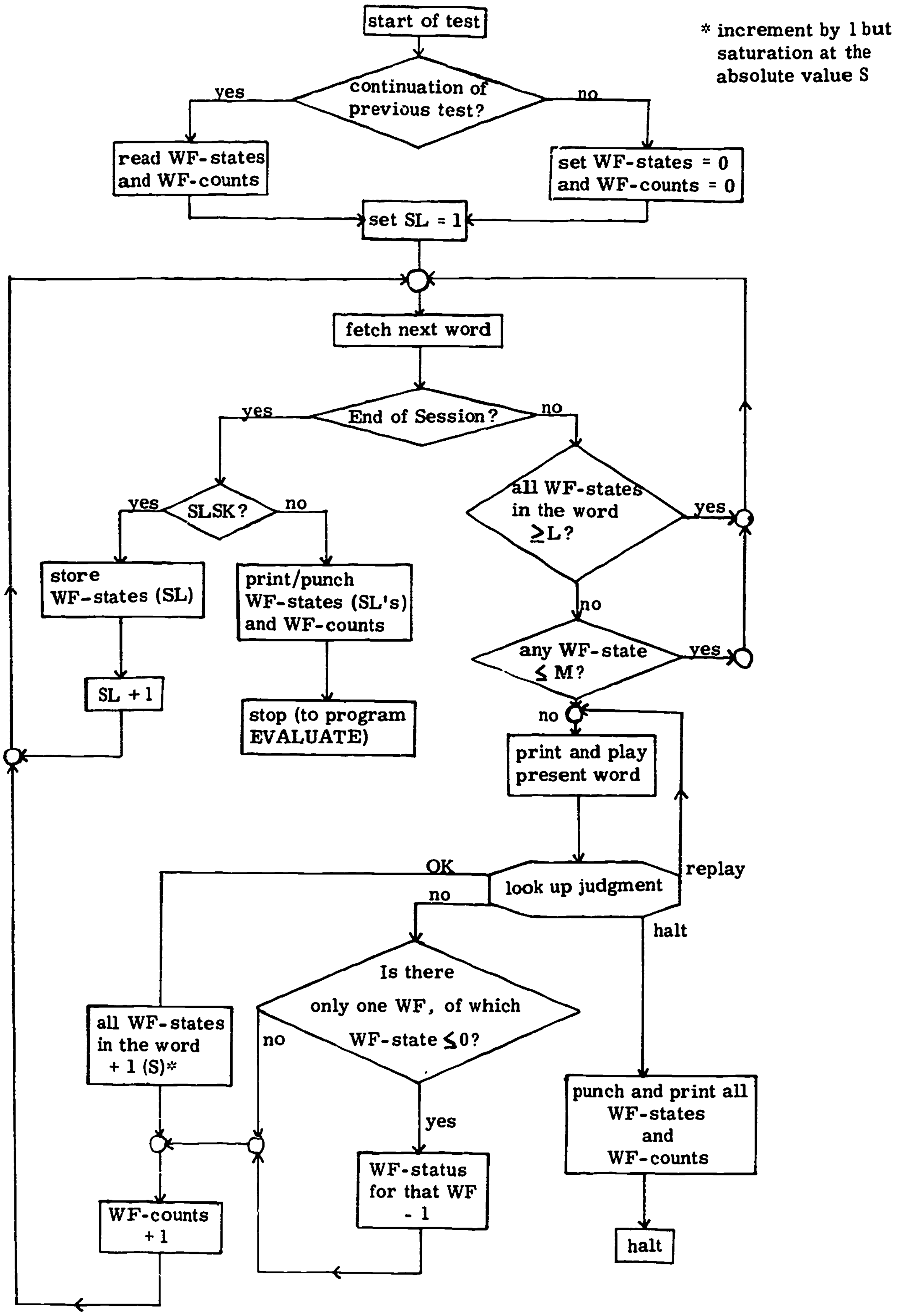

start of test
continuation of previous test?
yes
no
read WF-states and WF-counts
set WF-states = 0 and WF-counts = 0
set SL = 1
fetch next word
End of Session?
yes
no
SLSK?
yes
no
store WF-states (SL)
SL + 1
print/punch WF-states (SL's) and WF-counts
stop (to program EVALUATE)
all WF-states in the word ≥L?
yes
no
any WF-state ≤ M?
yes
no
print and play present word
look up judgment
OK
no
replay
halt
Is there only one WF, of which WF-state ≤0?
no
yes
all WF-states in the word + 1 (S)*
WF-status for that WF - 1
WF-counts + 1
punch and print all WF-states and WF-counts
halt
* increment by 1 but saturation at the absolute value S

Chart 19 Pronunciation Test Proceedings

TOAKT	*O
NARLZ	*N
STARVD	*O
YELPT	*O
WOARMZ	*O
TOARTJT	*O
MOWDZ	*N
TWELFTH	*O
TWELV	*O
RELMZ	*O
TUAFTS	*O
HWELMD	*N
SJRIJKT	*O
TWELVZ	*O
KOAPST	*N
GOANG	*O
BEJZJ	*N
SLEDZ	*N
SLIJVD	*O
GAWDJD	*O
TWAENGD	*N
HYUWDJ	*O
RUWZJ	*O
SLOJDZ	*O
SKARFS	*O

test proceeds, we obtain a flow of typed records of the student's performance as shown in Chart 19. The machine first types out the phonetic spelling of the coming word and plays the word for the student. Upon a signal by the computer (an asterisk typed out), the evaluator types in his judgment, O standing for OK and N for NO. The machine updates the WF variables, on OK incrementing all the WF-states of the WF's in the word by 1, and NO decrementing the WF-state if the WF is the only one non-positive among the WF's in the word. The machine then looks up the next label which is already read in, and decides if this should be adopted as the next sample or skipped according to the algorithm given in the flow chart.

At the end of the test, the computer types out the changing configurations of variables comparing the values of different session levels. Chart 20 illustrates an example of the computer typeout. The 6 columns to the right of the WF's in the identification symbols represent the states of the WF's at the end of the 1st level, the second level, and so on up to the sixth level. The right-most column shows the counts of the WF's at the end of the test. Peculiarities of both the student and the program can be read off these records. For example, if a particular student has negative values for the final states of some WF's, then he is judged to be poor in these WF's (e. g. -VZ in the example). By comparison of these marked WF's we will find some common features as constituents (segments or distinctive features) in terms of their phonetic properties. If these "elementary features" are already tentatively defined for WF's, then we can adopt these as a framework for this examination of correlations between WF's, and then by checking with the empirical results, we may revise the feature system itself. We will also obtain information about contextual interdependence of a pair of WF's,

Chapter 20 Computer Printout of the Test Record

```
-PS    : 0, 0, 0,01,01,01;003
-BZ    : 0, 0, 0,01,01,01;003
-GZ    : 0, 0, 0,01,01,01;001
-NGZ   : 0, 0, 0,01,01,01;001
-VZ    : 0, 0, 0,-4,-5,-5;005

-DTH   : 0, 0, 0, 0,00,00;002
-FTH   : 0, 0, 0, 0,01,01;001
-TTH   : 0, 0, 0,01,01,01;001
-KST   : 0, 0, 0,01,01,01;001
-PST   : 0, 0, 0,00,01,01;003

-DST   : 0, 0, 0,-1,-2,-2;004
-KSTS  : 0, 0, 0,01,01,01;001
-LTJT  : 0, 0, 0,01,01,01;001
-NTJT  : 0, 0, 0,01,01,01;001
-RTJT  : 0, 0, 0,01,01,01;001

-LBD   : 0, 0, 0,01,01,01;001
-LDJD  : 0, 0, 0,00,00,00;003
-NZD   : 0, 0, 0,-1,00,00;003
-RBD   : 0, 0, 0,01,01,01;001
-RVD   : 0, 0, 0,00,00,00;002

-RZD   : 0, 0, 0, 0, 0, 0;   0
-SPS   : 0, 0, 0,01,01,01;001
-LPS   : 0, 0, 0,01,01,01;001
-LBZ   : 0, 0, 0,01,01,01;001
-LVZ   : 0, 0, 0,01,01,01;001

-RBZ   : 0, 0, 0,01,01,01;001
-RVZ   : 0, 0, 0,01,01,01;001
-LFTH  : 0, 0, 0,01,01,01;001
-NGKST : 0, 0, 0, 0,01,01;001
-MPST  : 0, 0, 0, 0,01,01;001


LEVEL5

I      : 0, 0,01,01,09,09;027
UU     : 0, 0, 0, 0,02,02;003
UR     : 0, 0, 0, 0,01,01;001
F-     : 0, 0, 0, 0,04,04;007
V-     : 0, 0, 0, 0,01,01;001

TH-    : 0, 0, 0, 0,01,01;005
DH-    : 0, 0, 0, 0,01,01;001
L-     : 0, 0, 0, 0,07,07;011
PL-    : 0, 0, 0, 0,01,01;003
PR-    : 0, 0, 0, 0,01,01;002

BL-    : 0, 0, 0, 0,01,01;001
BR-    : 0, 0, 0, 0,01,01;005
```

in the form of a systematic deviation of the state values from the final value in some particular set of test words. And above all, if the WF-level assignment is inappropriate for some WF's, then the average score of many students must indicate a noticeable dip or peak of the states for these WF's compared to the WF's that are assigned the same level. If we find some WF's for which no definite conclusion is given, it indicates that we need some more word samples using these WF's. In order to facilitate these modifications and also preparation of "tailored homework tape" which typically would contain minimal pairs exemplifying the difficult contrast, we only need another program and a backup library of word samples.

The intention of this experiment is to try to automate the preparation and actual running of the test-training sessions as completely as possible and to see how much we can do about the semi-automatic growth of the teaching material. The experimental facility is of course somewhat limited at this state of experimentation, and the focus on the problem of pronunciation and hearing was partly due to this factor. Furthermore, we restricted ourselves to dealing only with monosyllabic English words. An extension to a more complete treatment of phonological problems of English is now being considered.

Pronunciation (or hearing) is of course one of the most difficult aspects of learing English for Japanese students. It is a particularly serious issue because the demand of learning English conversation is growing rapidly, but there are so few teachers who have firsthand experience of speaking English, since in the past opportunities for international personal contacts have been nearly nil for most Japanese people. It is not so much of a problem now to find a native speaker of English in the towns of Japan. The real problem is how to find a good teacher, and how to make the process of teaching as efficient as possible so that more and more people can be taught in the different ways particularly suited to each individual. This is relevant of course to teaching not only pronunciation, but also the language in general.

We are of course aware of some factors of the problem of automating language teaching, and we are not in the position to predict practical use of such programs as those discussed here in the near future. The experimentation, we believe, is certainly worth while from a research point of view, because the problem is complex but concrete enough. The computer-assisted preparation of the teaching material with some provisions of semi-automatic improvements is technically a challenging problem, of course. What we hope is, furthermore, that we will be able to gain understanding of the essentials of language and language behavior. The use of interactive computers makes it possible to handle the complex processes under sufficiently well-defined conditions, and to exploit the information obtained by efficiently processing it in postulated frameworks, in order to test the postulation.

Summary

Recent progress in special purpose tape-recording devices for language learning are discussed, and two preliminary experiments of English teaching for Japanese students are reported on. Both programs use an untrained native speaker as an evaluator. One is an oral repetition test-training program of sentences. Problems concerning optimization of the teaching course for individual students are dealt with by use of a multi-level structure of the test material combined with a multi-dimensional evaluation measure. For this purpose, a feature theoretical treatment of the problem is proposed along with a uniform patternization of branching structures of the logical plans for the lessons, making preparation of the teaching material quite feasible with assistance of an interactive computer. The other is a computerized test-training of pronunciation-hearing, and some technical details based on some experience are given. In both cases, possibilities of semi-automatic growth or improvements of the teaching material are claimed.