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ABSTRACT
                Methods for the implementation of on-line contingent
research are described in this study. In a contingent experimentation
procedure, the content of successive experimental trials is a
function of a subject's responses to a previous trial or trials (in
contrast to traditional experimentation in which the subject is
presented a previously established sequence of trials that is
constant for all subjects.) Computer control of the sequencing of
stimuli on the basis of the subject's responses permits the
adaptation of stimulus presentations to the response history of the
learner, facilitating the optimization of learning outcomes. The
manner in which contingent research designs enable the researcher to
examine learning problems that are analogous to the problems of
instructional technology is demonstrated, with particular emphasis
placed on the implications of contingent research techniques for task
management, psychological measurement, and research design. A
systematic analysis of contingent decision algorithms and on-line
programs is presented, and the application of these programs is
examined and compared with non-contingent research designs with
respect to procedure, data collection, and efficiency. (Author/MF)

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TECHNICAL REPORT

METHODOLOGICAL CONSIDERATIONS IN ON-LINE CONTINGENT
RESEARCH AND IMPLICATIONS FOR LEARNING

MARNA CUPP WHITTINGTON

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This study describes methods for the implementation of on-line contingent research in the learning laboratory. In a contingent experimentation procedure, the content of successive experimental trials is a function of a subject's responses to a previous trial or trials, (in contrast to traditional experimentation in which the subject is presented a previously established sequence of trials that is constant for all subjects.) Computer control of the sequencing of stimuli on the basis of the subject's responses permits the adaptation of stimulus presentations to the response history of the learner, facilitating the optimization of learning outcomes. The manner in which contingent research designs enable the researcher to examine learning problems that are analogous to the problems of instructional technology is demonstrated, with particular emphasis placed on the implications of contingent research techniques for task management, psychological measurement, and research design. A systematic analysis of contingent decision algorithms and on-line programs is presented, and the application of these programs is examined and compared with non-contingent research designs with respect to procedure, data collection, and efficiency.

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METHODOLOGICAL CONSIDERATIONS IN ON-LINE

CONTINGENT RESEARCH AND IMPLICATIONS FOR LEARNING

Marna Cupp Whittington

Learning Research and Development Center

University of Pittsburgh

October, 1970

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PREFACE

I would like to express my gratitude to Dr. William Ray for his thoughtful guidance and assistance throughout this study. Dr. Ray generously gave time and effort to the advising of this research. I would also like to thank Dr. Robert Glaser for his constructive suggestions and frequent communication despite the fact he was a Fellow at the Center for Advanced Study in the Behavioral Sciences in Stanford, California during the writing of much of this paper.

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METHODOLOGICAL CONSIDERATIONS IN ON-LINE

CONTINGENT RESEARCH AND IMPLICATIONS FOR LEARNING

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On-line usage of computers in the psychological laboratory
opens up new possibilities for research design and measurement.
One specific technique that has resulted from the on-line computer
capability is the contingent procedure in which a subject inter-
acts with the computer to determine stimulus presentation. In
the contingent procedure, a computer presents stimuli in a se-
quence contingent upon the individual responses of the subject,
according to the researcher's procedural design which specifies
a finite number of possible stimuli for presentation and decision
rules for determining which stimulus is to be presented at each
step in the program. Computer control of the sequencing of stim-
uli on the basis of the subjects' responses permits the researcher
much greater flexibility in the management of the research and
in the number and complexity of the stimuli presented during the
research.

Before this capability can be optimally used in the psych-
ological laboratory, consideration must be given to several im-
portant questions. For what research tasks is the contingent
procedure suited? For what purposes can the researcher use
contingent measurement? How should contingent research be designed?

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II. STATEMENT OF THE PROBLEM

Purpose of the Study

The purpose of this study is to investigate methods for conducting on-line contingent research in the psychological laboratory and to systematically explore the implications of contingent research for task management, psychological measurement, and research design.

Description of On-Line Contingent Research

Introduction of on-line contingent research procedures to the psychological laboratory necessitates a re-evaluation of the traditional methods of task management, psychological measurement, and research design. To adequately assess the impact of this new capability its distinguishing characteristics must first be delineated.

1. Presentation of stimuli can be made contingent upon the subject's responses to previous stimuli. The result is continuous adaptation of the stimulus sequence on the basis of the subject's response history.

2. Computer management of procedure provides greater standardization of research. The on-line computer can uniformly administer the entire research procedure according to the algorithm developed by the researcher.

3. Computer management reduces error. The on-line computer collects and records the data while the research is in progress, thereby eliminating human recording and transcribing errors.

4. Computer memory capacities and access times make more quickly available a broader range of stimuli for presentation during research than is feasible with most traditional apparatus. The scope of possible stimuli is increased both in number of stimuli available and range of stimuli available. That is, software developments in interfacing have provided random access audio units, touch sensitive screens, and cathode ray tubes. These interfaces can be used individually or in groups, making possible the simultaneous presentation of audio, visual and tactual stimuli.

5. On-line computers can administer complex research procedures that were previously impossible to implement with traditional apparatus. For example, in verbal recall research Maitland (1970) presented all subjects a 40 word list for recall. On trial 1 the presentation order of the 40 words was constant for all subjects. On the trial 2 presentation each member of the maintained order treatment group was presented the list in the order in which he had recalled them on trial 1. Unrecalled words were randomized and placed at the end of the presentation list. Each succeeding presentation order for the maintained order

group was contingent upon the subject's immediately
previous recall.

6. Increased standardization of research procedure reduces
error variance and facilitates the detection of effects
on the dependent variable (Johnson, 1967).

On-line contingent research procedures that bring the pre-
ceding capabilities into the psychological laboratory are con-
trolled by contingent programs written by the researcher. Con-
tingent programs can be classified by the degree of complexity
involved in the algorithm for the stimulus sequencing decisions
made in the program. The degree of complexity of the algorithm
is measured by the number of variables the algorithm considers
in determining the appropriate stimulus to present at each step
of the procedure. A program classification based on complexity
will be outlined here for reference in this study. There is
presently no standard classification procedure. Since in many
cases program decision types are mixed within programs and are
not distinct from program to program agreement among researchers
would be difficult to obtain. However, the advantages of having
an orderly classification for reference and description purposes
offset the disadvantages of the possible disagreement and the
inflexibility resulting from a classification.

The three types of contingent programs that are distinguished
by the complexity of the stimulus sequencing algorithm are:

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a) single stage decision process;

b) multistage decision process; and

c) multistage decision process incorporating extra-program
history parameters.

Contingent programs with single stage decision processes
have the least complex algorithm for stimulus sequencing. In the
single stage decision process only the subject's immediately pre-
vious response and not his response history is considered in the
stimulus presentation decisions. This decision process can be
represented by the function:

$$S_n = f(R_{n-1}) \tag{1}$$

S_n = stimulus to be determined

R_{n-1} = subject's response to S_{n-1}

n = program sequence number for stimuli and responses

The single stage decision process is easily implemented
because the decision algorithm has only one variable. The re-
maining decision parameters are determined by the researcher
before the program is written and are constant across all sub-
jects. For example, in a hypothetical third grade math curriculum
there is a program to teach long division by a single stage deci-
sion process. In this teaching program, each child receives step-
by-step instructions on the long division process and is asked
to respond in some manner at each step. The single stage program

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responds to his correct or incorrect response appropriately
and uses his successful or unsuccessful response to determine
the next stimulus presentation. This procedure provides adap-
tive treatment for each subject on the basis of his immediately
preceding response. However, if two students receive frame 6,
one after a series of errors and one after a series of correct
responses, and both miss frame 6, the first because of lack of
knowledge and the second because of carelessness, the single
stage program treats them identically because only the wrong
response is used in determining stimulus sequencing.

Programs with a multistage decision process involve more
complex stimulus sequencing decisions than do the single stage
programs. In the multistage programs the subject's entire
response history for a program may be considered in the stimulus
presentation decision. This decision process can be represented
by the function:

$$S_n = f(R_1, R_2, R_3, \ldots, R_i, \ldots, R_{n-1}) \tag{2}$$

S_n = stimulus to be determined

R_i = subject's response to i^{th} stimulus

n = program sequence number for stimuli and responses

Programs utilizing the multistage decision process vary
widely in complexity depending upon how long the program is and
how the responses in the program are handled for decision purposes.

If each response made is considered a variable in the decision
algorithm, the decision process at frame n would have n-1 vari-
ables to consider in the selection of the next stimulus. How-
ever, in some programs groups of responses are assigned single
values, thus the multiplicity of variables is reduced. For
example, in a learning program the first ten frames might consti-
tute a subset of frames within the program which would be assigned
a single performance value after the subject had completed all
ten. This single performance value would then be used instead
of ten single response records in the decision process for later
stimuli. In this situation the general function (2) for multi-
stage decision process stimulus determination would be modified:

$$S_n = f(g(R_1, R_2, \ldots, R_{10}), R_{11}, R_{12}, \ldots, R_i, \ldots, R_{n-1}) \quad (3)$$

S_n = stimulus to be determined

$g(\,)$= single-valued functional composite of R_1-R_{10}

R_i = subject's response to i^{th} stimulus

Even with this possible simplification, the consideration of more
than one previous response greatly increases the complexity of
the multistage decision process as compared to the single stage
process. For example, if the single stage division program
discussed earlier were modified to consider all six of the
subject's responses in the stimulus presentation decision, it
would be reclassified as a multistage program. In the multistage

version, after the two students missed frame 6 in the teaching sequence they would each have a history file containing six records. Records 1-5 could be any one of 2^5 combinations of incorrect or correct responses. Including frame 6 this makes a possible total of 2^6 different response histories for students completing frame 6. These 2^6 different response histories would be used for the stimulus presentation decision rather than just the correctness or incorrectness of frame 6. Although there may not be 2^6 different and relevant stimulus presentations for frame 7, the increase in complexity of the decision on stimulus presentation is apparent. This increase in decision complexity also provides an increase in flexibility for adaptation of the teaching sequence. Instead of both students receiving the same stimulus 7 as they did in the single stage program, the careless student might be given the next step in the teaching sequence whereas the student genuinely lacking knowledge might be restarted on the program or branched to an easier remedial frame.

The most complex decision procedure is the multistage procedure with extra-program history parameters. In this decision procedure the subject's entire program response history and specified history parameters outside of the program are considered in the stimulus sequencing decision algorithm. The extra-program history parameters are entered into memory prior to the running of each subject. The decision process can be represented by the

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function:

$$S_n = f(H_1, H_2,...,H_j,...,H_m, R_1, R_2,..., R_i,..., R_{n-1}) \qquad (4)$$

S_n = stimulus to be determined

H_j = subject's j^{th} extra-program history parameter

R_i = subject's response to i^{th} stimulus

Examples of possible extra-program history parameters are the subject's performance on previous programs, the subject's age, and the subject's ability. Depending upon the number and type of history file variables added to the decision procedure, the multistage decision process with extra-program history parameters can become extremely complex and comprehensive. For example, if the multistage decision process division program discussed earlier were modified to include the subject's IQ, math aptitude test scores, and previous math program scores as variables in the stimulus sequencing decision process, the program would be reclassified as a multistage decision process program with extra-program history parameters.

In this new version of the division program the two subjects previously discussed might not have both received frame b. The slower student might have an extra-program history containing an IQ of 90, low math aptitude scores, and a record of previous difficulty with math programs. The quicker student might have an extra-program history containing an IQ of 125, moderately high

math aptitude scores, and a record of fast learning on previous

math programs. Consequently the slower student would progress

through the program in small steps receiving a large amount of

stimulus redundancy. The faster student would progress in large

steps and possibly skip complete sections of material on which

he had demonstrated mastery in preliminary testing.

Presently many of the learning laboratory programs can be

classified as single stage decision process or multistage decision

process programs. Examples of single stage decision process pro-

grams are the branched testing programs in which stimulus decisions

are based on the correctness of the immediately preceding response

and are independent of early program frames and extra-program

history parameters (Bayroft and Seeley, 1967). Examples of the

multistage decision process programs are concept formation research

programs (Johnson, 1967), verbal learning research programs

(Maitland, 1970), and instructional research and teaching programs

(Suppes, 1968). Theoretical programs nave been developed using

the multistage decision process program with extra-program history

parameters but few if any of these are implemented yet (Groen and

Atkinson. 1966; Karush and Dear, 1966; Smallwood, 1967).

In some single stage and multistage decision programs con-

sideration is indirectly given to extra-program history parameters

before the program is run and is not part of the program decision

procedure. For example, the pretesting and selecting of subjects

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for a specific program by IQ or achievement test scores account

for extra-program variables without incorporating them directly

in the stimulus sequencing decision procedure.

One reason for not including history files as part of

standard decision procedure is the increase in complexity it

brings to the program. However, a more important reason is the

lack of empirical data on the interaction of extra-program history

parameters with the contingent stimuli presented in the program.

To use history parameters advantageously and thus benefit from

the increased program decision complexity the researcher must

have a detailed knowledge of the relationship between the program

objectives and the extra-program information available for each

subject. Presently these detailed data do not exist for many

types of research. The more general information that is avail-

able, for example, on aptitude or age, can be adequately assessed

in pre-program selection procedures.

To date, these three decision procedures, the single stage

decision process, the multistage decision process and the multi-

stage decision process with extra-program history parameters, are

the basic decision procedures used in the majority of contingent

programs. However, these three decision procedures do not separ-

ate all contingent programs into three distinct classes. Many

programs include both single stage and multistage decision pro-

cesses in the same stimulus sequencing decision algorithm.

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History of Contingent Research

Psychophysicists were the first researchers to employ con-
tingent programming in the psychological laboratory. The rela-
tively straightforward nature of the psychophysical research task
led to the early implementation of contingent computer programs
and facilitated the development of the contingent techniques
presently in use. Since the most extensive use of contingent
research is still in psychophysics, it is appropriate to discuss
in detail the procedures used, keeping in mind that psychophysical
research requires less flexibility in the contingent program
than does most other contingent psychological research.

The specific tasks in psychophysical research are the deter-
mination of absolute thresholds, difference thresholds, and per-
centage points on subjective response curves, i.e., the values
of stimuli that will evoke a specified response on some specified
percentage of occasions. For all three tasks the psychophysicist
records judgements of varying levels of stimulus intensity and
uses these judgements to determine the percentage of responses
in each category at each stimulus level. By running enough
subjects on an appropriate range of stimulus intensity levels
the psychophysicist obtains normative response data which he
examines to answer the psychophysical question being explored,
i.e., the value of the absolute threshold, the difference threshold,
or particular response points of the stimulus being investigated.

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In these specific tasks psychophysicists use the contingent procedure to narrow the range of stimuli presented and concentrate observations in the region of the stimulus continuum providing the most information about the question defined in the psychophysical problem. Prior to the implementation of the contingent procedure, psychophysicists explored the entire stimulus continuum, arbitrarily presenting stimulus levels chosen at spaced intervals across the range of possible stimulus intensities.

Two general methods of contingent research in psychophysics are outlined in the following paragraphs. In the examples given a simple yes-no response restriction is imposed to simplify and clarify the discussion of the methods. For example, in a psychophysical task determining the absolute threshold of an auditory stimulus, a "yes" response means the subject heard the stimulus presented and a "no" response means the subject failed to hear the stimulus.

The method of ascending limits, the simplest form of contingent programming in psychophysics, is employed when the psychophysical objective is the determination of specific response percentile points on a stimulus continuum. Each percentile point is determined by the following procedure. An initial stimulus level is predetermined by the researcher and presented to the subject; if the subject's response to this level is "no" the next more intense stimulus is presented; if the subject's response is

"yes" the starting stimulus is presented again. The subject

continues to receive stimuli of increasing intensity with each

"yes" response and to return to the starting stimulus with each

"no" response. By repeatedly approaching the "yes" response

intensity from the less intense side of the stimulus continuum,

the method of ascending limits focuses on the response percentile

point on the stimulus continuum. This method usually involves

a single stage decision process, that is, only the previous "yes"

or "no" response is used to determine the next stimulus level to

be presented. However, a multistage decision process version of

this method that utilizes a run of two or more positive responses

to terminate the run of increasing response intensity has also

been developed.

The up-down transform, a second psychophysical method, is

generally used for establishing the value of the absolute threshold

on a stimulus continuum. In the up-down transform a "yes" re-

sponse is the occasion for the next less intense stimulus to be

presented and a "no" response is the occasion for the next more

intense stimulus to be presented. The stimuli are usually ar-

ranged along the continuum in equal steps that have been prede-

termined by the researcher and calculated prior to the program

for the particular stimulus being researched. The up-down trans-

form method has also been modified by replacing the single stage

algorithm by a multistage algorithm requiring more than one "yes"

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or "no" response to change the direction of the intensity of the
stimuli presented.

The method of ascending limits and the up-down transform
are both examples of the general methodology of contingent pro-
grams used in psychophysics to establish values such as specific
response points and absolute thresholds.

A specific program designed by Taylor and Creelman (1967)
for psychoacoustical research and called Parameter Estimation
by Sequential Testing (PEST) is described in the following pages
as it is presently implemented. This description will first
outline the stimulus sequencing information that must be built
into every contingent psychophysical program and then describe
the specific stimulus sequencing features of the PEST program.
The goal of PEST is the goal of all contingent psychophysical
research: to converge on the selected target level by use of
maximally efficient trial-by-trial sequential decisions at each
stimulus level.

All contingent psychophysical programs must include four
types of information in the stimulus sequencing algorithm
(Taylor and Creelman, 1967).

    1. Specific rules for determining when the level of the
       stimulus presented should be changed.

    2. Specific rules for determining to what level the stimulus
       should be changed if the decision has been made in 1)
       that it should be changed.

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3. Rules for terminating the program. (These rules are a function of the amount of error the psychophysicist is willing to tolerate in his data. Without a preset end criterion the procedure continuously approaches the target value in increasingly smaller and eventually infinitesimal steps.)

4. Rules for calculating the targetlevel at the end of the procedure.

In PEST the subject is presented with an arbitrary starting stimulus value and then control of stimulus presentation is turned over to the computer. The following program decision rules satisfy information requirements 1. and 2.

1. On every reversal of step direction, the step size is halved.

2. The second step in a given direction is the same size as the first step.

3. The fourth and subsequent steps in a given direction are each double their predecessor; however, the researcher has an option of placing an upper limit on permissable step size.

4. A third successive step in a given direction is the same as the second if the step preceding the most recent reversal resulted from a doubling of step size; if the step leading to the most recent reversal was not the result of a doubling then this third step is double the second.

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In satisfying the third requirement, PEST runs continuously until the decision algorithm calls for a step of some minimum size previously determined by the researcher. The fourth requirement is satisfied by designating the final level of the stimulus presented before the procedure is terminated as the target level.

Taylor and Creelman have used PEST frequently with both naive and experienced subjects using signal amplitude as the independent variable. They have found that the task involved in PEST is easy for the subjects; the contingent procedure is easy to run; and the analysis of the data is straightforward.

The method of ascending limits, the up-down transform, and PEST all demonstrate that the major advantage of contingent programming in psychophysics is the capability of specifying a point or points on the psychometric function without first determining the whole function and then extracting values for the critical points. By zeroing in on a specific point and not exploring informationless stimulus levels all research effort is directed to determining accurate estimates for the points on the response curve that are in question.

Before psychologists could implement the contingent psychophysical methods in psychological research other than psychophysics the methods had to be proven applicable. Two major questions facing the psychologists were: 1) Can the computer effectively administer complex contingent sequences of stimuli

other than the psychophysical stimuli? 2) Are there psychological

continua analogous to psychophysical continua and, specifically,

can task difficulty be treated as are intensity continuum and

be "stepped up and down" effectively? If so, does this capability

have any psychological merit? Obviously, a simple yes-no answer

is not broadly applicable to either question. However, two

important studies in the early stages of the development of

contingent psychological research did show the feasibility and

merit of computer administration of complex research procedures

(Johnson, 1967) and of the process of stepping up and down a

continuum of item difficulty (Mclaragno, 1967). These two studies

are outlined in the following pages.

Johnson (1967) used a concept formation task administered

by an IBM 1620 and research assistants to analyze the advantages

and disadvantages of computer task presentation. In the task

subjects were presented with 32 pattern blocks, four of which

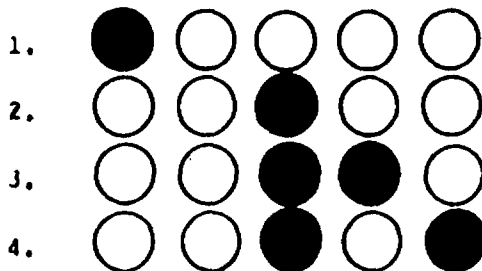are shown in figure 1. The subjects were told that these 32

Figure 1. Four Pattern Blocks Used in Johnson's Concept
Formation Task

blocks could be grouped into two distinct subsets in a large number of ways; i.e. grouped on the basis of total number of black dots present; grouped on the basis of the color of one particular dot position; or grouped on the basis of a pair of dot positions. The subject was presented one block and its classification as red or green during each frame of the program. After each presentation of a block the subject's task was to hypothesize an appropriate classification rule.

The subject typed his hypothesis on a teletype in the interface language he had been taught at the beginning of the program. His hypothesis was checked for grammatical legality, validity and correctness. Validity was determined by the consistency of the hypothesis with the information the subject had received in previous frames. If the hypothesis was grammatically illegal the subject was asked to retype it; if it was inconsistent the subject was asked to make up another one. If the hypothesis was grammatical and consistent but not correct the subject was presented with a block that would contradict the classification rule he had hypothesized. The decision algorithm always presented the most efficient sequencing of blocks by presenting the subject with a pattern that would refute his current wrong hypothesis. Eventually the subject acquired enough information to grammatically, validly, and correctly induce the proper classification rule.

Johnson presented this procedure to each subject twice, once administered by a research assistant and once by an IBM 1620, to explore the differential presentation effects.

Johnson's results showed that the mean performance did not differ significantly in the two presentation conditions. However, the variance in performance in the computer administered condition was reduced. Johnson attributes this difference to a reduction in error variance resulting from the automation of the research procedure. Johnson states that this reduction in variance is particularly significant because it implies that computer-administered research should be more sensitive to independent variable manipulations because main effects are less apt to be masked by error variance. Johnson's data also showed that the IBM 1620 outperformed the research assistant in assessing the validity of the subject's hypothesis and in selecting the next pattern for presentation.

Johnson's results favor the implementation of contingent programs in the psychological laboratory for task management and procedural reasons. His study empirically demonstrates the feasibility of computer administration of complex contingent sequences of stimuli.

Melaragno (1967) used three versions of an instructional program for geometric inequalities as treatments in an experiment to compare the effectiveness of adaptive and non-adaptive teaching

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procedures. The three treatments were a linear program, a branched program, and a prediction program. The linear program, as the control program, was not contingent, that is, it presented the same set of stimuli to each subject regardless of his entry behavior and his program performance. The branched program was contingent in that it altered the instructional sequence on the basis of the correctness of the subject's responses. The branched program treated the item difficulty continuum as a psychophysical continuum and stepped up and down it, adapting the difficulty of the item presented on the basis of the correctness of the subject's responses. The prediction program pretested the subject's entry behavior and routed the subject to the appropriate form of a linear program on the basis of the subject's pretest score.

Melaragno's study was conducted in two phases. In the first phase, empirical trials of self-instructional programs were carried out to assess the value of branching logic and to determine the appropriate branching strategies and program frame sequences for each treatment program on the specific subject matter, geometric inequalities, used in the study. The second phase of the study, conducted in a computer-based instructional laboratory, presented the linear, branched and prediction programs developed in phase 1 to the subjects and assessed the relative effectiveness of the three methods of instruction.

In the first phase, thirty-two high school students were

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administered seven pretests and the developmental program. The
developmental program consisted of six units: units 1-5 covered
theorems, axioms and postulates for geometric inequalities; unit
6 taught proof of theorems. At the end of each of the six in-
structional units, the subjects were given a quiz on the material
covered and a discussion section on the questions and appropriate
answers for the quiz just completed. Detailed performance records
were kept for each subject to determine specific program locations
that needed remedial instruction and specific sequences that
should incorporate larger steps for the more able students. The
posttest for the program consisted of 57 points: 29 points for
tasks directly related to the content of the program; and 28
points for tasks related to transfer situations.

From these data a final program was developed that consisted
of 248 teaching items, 20 testing items, and 30 remedial items.
The subjects' seven pretest scores were evaluated in relation to
their posttest scores and these data were used to establish
assignment rules for the subjects in the prediction group.

In the second phase of the study, the geometric inequalities
program developed in phase 1 was used to evaluate the three types
of instruction. A total of forty-four high school students were
randomly assigned to the treatment conditions. The experiment
had a completely randomized design with three groups. The three
types of instruction were the treatments and the scores on the

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posttest and the training times were the dependent va.·iables.

The linear program treatment group received the 248 main instruction items, 20 quiz items, and 17 remedial instruction items.

The branched program treatment group progressed through the program with all branching decisions made on the basis of their prior performance and their quiz scores at the ends of the previous units.

The prediction program treatment subjects each received a linear program judged appropriate for them on the basis of their pretest scores.

Melaragno's results showed a significant ordering of the three treatment groups on the basis of posttest scores. The branched treatment was the most effective, the prediction treatment next, and the linear treatment least effective. The training times showed that the branched instructional program produced superior posttest scores with a significant savings of time.

The performance of the subjects in the branched treatment group empirically demonstrated the feasibility and merit of implementing contingent procedures in the research of psychological continua. As in psychophysics, the branched treatment procedure saved time and produced comparable or better results when compared with the linear procedure.

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Johnson and Melaragno's studies have provided positive

answers to the two questions of teasibility: 1) Can the computer

eftectively administer contingent sequences ot complex stimuli?

and 2) Can a psychological difficulty continuum be considered

analogous to a psychophysical continuum and be treated as a

psychophysical continuum? The implications of implementation

of on-line contingent procedures in psychological research will

be considered for task management, psychological measurement,

and research design.

III. IMPLEMENTATION OF ON-LINE CONTINGENT PROGRAMS IN THE
PSYCHOLOGICAL LABORATORY

The primary purpose of this study is to explore possibilities
for the conduct of on-line contingent research in the learning
laboratory. Information on both contingent programs and on-line
usage of computers in laboratory research has been presented.
The discussion will now focus on the primary question - What
possibilities are there for the additional use of on-line contingent
programs in the psychological laboratory?

Several characteristics of on-line contingent programs
should be specifically recalled and considered when answering
this question. First, in this type of research subjects are
treated as individuals who may respond alike when treated differ-
ently and differently when treated alike. No attempt is made
prior to the beginning of the research procedure to fix the series
of stimuli they should receive. After all the subjects have
completed the contingent program, each can be assigned a track
number that represents the set of stimuli he received during the
program. If the researcher chooses, in his data analysis all
subjects following the same track through a program can be con-
sidered as a group or supply defined for further research.

A second unique characteristic of on-line contingent programs

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is the procedure used in stimulus sequencing. The presentation
of stimuli is determined by the subject's responses. Thus
different subjects may receive different stimulus sequences and
differing total numbers of stimuli. Unlike traditional research
designs that present a constant number of stimuli to all subjects
in the same treatment group, the contingent procedure makes no
attempt to equate the number of stimuli presented to each subject.
With these two unique characteristics to consider, a study of
the possible applications of contingent research procedure to
psychology was carried out.

The implications of on-line contingent programs will be
considered in three phases of psychological research: 1) task
management; 2) measurement; and 3) design. As Uttal (1969)
states, "the truly automated laboratory is in its early stages
of development" so there are few published examples of the new
techniques and the research that is in the literature is not
completely developed or analyzed.

Task Management

The nature of the task in psychological research is deter-
mined by the problem outlined by the researcher. Since the
specific task involved in the research problem determines the
applicability of on-line contingent procedure to task management,

three specific kinds of tasks frequently studied in the learning
laboratory have been selected for examination: 1) discrimination
learning tasks; 2) transfer learning tasks; and 3) concept for-
mation tasks.

Discrimination Learning Tasks

Discrimination is operationally defined as responding
differentially to different stimuli. In an empirical sense
discrimination is the opposite of generalization and discrimin-
ation learning is the process of breaking down generalizations.

Discrimination learning is usually a gradual process taking
place over a number of trials that serve to orient the subject
to the relevant features of the stimulus. If the subject does
not attend to the discriminative features he will not obtain
the information necessary to solve the discrimination problem.

The general method required to produce a discrimination
involves the simultaneous extinction of generalized responses by
non-reinforcement and strengthening of the discriminative response
by reinforcement. Two traditional research techniques are used
to accomplish this task: 1) the method of successive presentation
of stimuli; and 2) the method of simultaneous presentation of
stimuli (Kimble, 1961).

In the method of successive presentation of stimuli only
one stimulus is presented on each trial - either the stimulus
requiring and reinforcing a response (the positive stimulus)

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or a stimulus requiring no response (the negative or generalized stimulus).

In the method of simultaneous presentation of stimuli the positive and the negative stimuli are presented together and the subject must respond to the positive stimulus.

In what manner can the contingent procedure be applied to these discrimination task procedures?

The contingent procedure can be used to incorporate stimulus shaping techniques in discrimination learning tasks.

In non-contingent discrimination tasks the stimulus shaping technique attempts to teach subjects an errorless discrimination by beginning with a very easy discrimination and presenting a series of progressively more difficult discriminations. The final discrimination in the series is the discrimination traditionally presented throughout a standard simultaneous presentation procedure. In the stimulus shaping procedure the positive stimulus in the initial easy discrimination remains constant and is reinforced for all succeeding discriminations in the series. The negative stimulus in the initial discrimination is a highly discriminate version of the final negative stimulus in the stimulus response relation the researcher is trying to teach. The non-contingent stimulus shaping procedure gradually shapes the initial negative stimulus until it is identical to the negative stimulus in the discrimination task being taught. The step sizes in the shaping sequence are those judged most facilitating for the

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majority of the subjects. The step sizes are predetermined by the researcher and are constant for all subjects. The stimulus shaping procedure attempts to have every subject practice and master each discrimination in the shaping process and discriminate the final step with no errors.

The merits of the stimulus shaping procedure are demonstrated by an experiment done by Sidman and Stoddard (1967). Sidman and Stoddard presented nineteen retarded boys with a circle-ellipse discrimination task. The control group received a traditional simultaneous presentation of stimuli program to teach the discrimination; the experimental group received a stimulus shaping program. The results showed a significant difference in the performance of the two groups. In the control group, only one of the nine subjects learned the discrimination. However, in the experimental group seven out of ten subjects learned to discriminate between the circle and the ellipse. This data clearly supported Sidman and Stoddard's hypothesis that the stimulus shaping program could teach the retarded students more effectively than could the traditional discrimination learning program. Similar results have been shown for normal children (Hively, 1962; Holland and Matthews, 1963; Moore and Goldiamond, 1964; Suppes and Ginsberg, 1962 a, 1962b).

The implementation of efficient stimulus shaping programs for discrimination tasks is hampered by two recurrent problems:

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1. The same step sizes in the stimulus shaping sequence are
   not equally effective for all subjects. Some subjects
   can learn the discrimination with large shaping steps
   while others require very small steps.
2. Subjects require differing numbers of practice trials
   on each step of the stimulus shaping procedure to ensure
   mastery of that step.

In a contingent stimulus shaping procedure, the step sizes
in the stimulus shaping process and the number of practice trials
on each step could be individualized. By making the presentation
of stimuli contingent on each subject's responses and response
latencies, the contingent shaping procedure could ensure that each
subject would receive the stimulus sequence most suited to his
learning capabilities and would master each discrimination step
before progressing to a more difficult discrimination.

The contingent capability of efficiently teaching an error-
less discrimination task has important practical application in
the individualization of instruction now receiving much attention
from educators and in the teaching of students previously incapable
of learning from traditional training procedures.

Transfer Learning Tasks

The transfer of learning problem is the study of the inter-
ference or facilitation of previous learning on new learning.

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There are two basic research designs for transfer studies:
1) the proactive design; and 2) the retroactive design. Both
designs require two groups of subjects.

In the proactive design group 1 practices task A and is
tested on task B; group 2 rests while group 1 is practicing
task A and is tested on task B also. The difference in the
performances of groups 1 and 2 is attributed to the transfer of
learning from task A to task B.

In the retroactive design group 1 practices task A, prac-
tices task B and is tested on task A. Group 2, the control
group, practices task A, rests, and is tested on task A. The
difference in the performances of groups 1 and 2 on task A
retest is attributed to the interpolated practice on task B.

In what ways can the contingent procedure be used in transfer
of learning research?

In transfer of learning tasks, the contingent procedure
allows the researcher the flexibility of choosing task B con-
tingent upon the subject's performance in task A. When subjects
receive the same physical stimuli the effect of the stimuli may
differ from subject to subject. It is also true that subjects
receiving different stimuli may respond the same. In contingent
transfer learning procedures task B can be adapted on the basis
of subjects' differing responses to a constant task A.

A summary of "Transfer Effects in Whole/Part Free Recall",
a verbal recall experiment done by Tulving and Osler (1967), is
presented below. A proposed revision that incorporates a con-
tingent decision procedure to modify task B on the basis of the
subject's performance on task A follows the description of the
traditional transfer of learning design.

Tulving and Osler examined the transfer effects in list
learning tasks and the implications of the transfer effects for
two current contradictory verbal learning hypotheses. The first
hypothesis, the independence hypothesis, is that recall of a
given item on a list is not influenced by recall or non-recall
of any other item or items on the list. The second hypothesis,
the interdependence hypothesis, is that words are organized into
higher order memory units and recall of a word is greatly influ-
enced by recall or non-recall of other words in that unit.

The design of Tulving and Osler's experiment was a 3x2
factorial. Each of the six groups of subjects learned two lists
of nouns: the first list consisting of 18 words; and the second
list consisting of 9 words. The first factor in the experiment
was three levels of practice on the first list: 6 trials; 12
trials; and 24 trials. The second factor was the list relation-
ship. The three experimental groups received a second list com-
posed of 9 words randomly selected from the first list. The
three control groups received a second list composed of 9 new

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nouns.

Tulving and Osler's results showed a significant negative transfer from task A to task B for the three experimental groups.

If Tulving and Osler's experiment were rerun with a contingent decision procedure, the choice of words in the experimental group's second list could be made contingent on their performance on the first list. By defining rules for choosing list 2 rather than specifically predeterminimg each item, specific transfer situations could be established for each subject on the basis of his performance on task A.

For example, to examine the validity of the two hypotheses a series of four experiments identical in format to Tulving and Osler's could be run. In each experiment the experimental and control groups would receive the same task A, a list of 18 words to recall. Task B for the control group would be a list of 9 unrelated words. Task B for the experimental groups would be defined by a set of rules for choosing 9 items from list 1 on the basis of the subject's performance on task A.

Experiment 1: A list composed of the 9 words the subject learned first in task A.

Experiment 2: A list composed of the 9 words the subject learned last or failed to learn in task A.

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Experiment 3: A list composed of the 9 words most often appearing
together in the recall protocols of the subject
during task A.

Experiment 4: A list composed of the 9 words least often appearing
together in the recall protocols of the subject
during task A.

In each of the experimental groups the items presented in task B
are contingent upon the subject's performance on task A. Thus
the subjects within an experimental group would receive different
stimuli on the basis of their past performance. However, all the
stimuli presented to subjects within a treatment group would
share a defined characteristic relevant to a specific transfer
problem. By adapting task B items for each subject, the researcher
is able to present to every subject within a treatment group the
same transfer situation,

These are just a few of the possibilities for contingent
experiments to explore the transfer process in recall. This
contingent technique has important implications for transfer of
learning research because it permits the researcher to eliminate
from his data some of the "effect noise" to which Smith (1967)
referred and to explore separately each facilitating or inter-
fering characteristic of a task in a transfer of learning study,

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Concept Formation Tasks

Concept formation tasks require the subject to learn and
apply a definitive set of properties. A concept is defined as
"a class or category all the members of which share a particular
combination of critical properties not shared by any other class"
(Markle and Tiemann, 1970). Persons who have learned a concept
need not be able to verbalize it but must be able to discriminate
non-members of the class from members of the class. Thus dis-
crimination and identification are the basic operations in con-
cept learning.

There are generally two methods used in concept formation
problems: 1) identification method; and 2) response method.

In the identification method the subject is usually pre-
sented with the entire sample of stimuli and asked to choose one
from the sample. The researcher then tells him whether the one
he chose is an example of the concept. The subject continues
picking objects until he has chosen a long string of correct
choices (the number needed is the preset criterion for concept
attainment).

In the response method the subject is given a stimulus and
he must name the concept. The subject guesses at a name and
the researcher tells him right or wrong and supplies the correct
name. The researcher continues presenting stimuli to the subject
until he has a long series of successes at naming the concept

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represented by each stimulus presented.

In what ways can the contingent procedure be applied to concept formation research?

The contingent procedure can be used in concept formation tasks to present the most efficient stimulus sequence for concept learning to each subject. If the stimulus presented were made contingent upon the subject's previous response, a stimulus contradictory to the most recent hypothesis could be presented at each trial. A contradictory stimulus would provide the subject maximal possible information about the correctness and incorrectness of his present hypothesis.

For example, in Johnson's (1967) experiment outlined on pages 18-19, contingent stimulus presentation is used with pattern blocks. In this experiment, the subjects were presented 32 blocks and told the blocks could be grouped into two distinct subsets in a large number of ways. The subjects were presented one block and its classification as red or green during each frame of the program and their task was to hypothesize the appropriate classification rule. If the subject's hypothesis was incorrect he was presented a block that would contradict the classification rule he had proposed. An example of a stimulus response sequence for an easy concept formation task is outlined on the following page.

Stimulus 1: ● ○ ○ ○ ○   Green

Hypothesis: Green blocks have the first dot black.

Stimulus 2: ● ● ○ ○ ○   Red

Hypothesis: Green blocks have one dot black.

Stimulus 3: ● ○ ● ○ ○   Green

Hypothesis: Green blocks have the odd dots black.

Stimulus 4: You are correct. Green dots do have the
             odd dots black.

By presenting the blocks contingent upon the subject's most
recently hypothesized concept the program provides an efficient
sequence of frames that provides maximal information about the
correctness and incorrectness of the subject's recent response.

       The incorporation of the contingent stimulus presentation
procedure reduces the complexity of the traditional concept
formation task. The contingent procedure presents only those
stimuli relevant to the dimensions or concepts on which the
subject is presently focused and not a confusing sample of the
entire population of stimuli available. This contingent

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procedure offers the learning researcher a more effective technique for teaching concepts that have traditionally been time consuming and difficult for the students.

Measurement

The methods for using the contingent procedure in psychological measurement are determined by the researcher's application of the resultant measure. There are three basic applications for contingent measurement:

1. placement of subjects on a psychological continuum;

2. classification of subjects into supplies for description or further research; and

3. assignment to subjects of a classification score predictive of other variables with criterion status.

The contingent measurement procedure, often referred to as a branched or tailored test, was developed from the psychophysical testing procedure by treating the psychological continuum of the parameter to be measured as a psychophysical continuum of stimulus intensity. As in psychophysics, the contingent measurement procedure reduces measurement time by focusing on frames most informative about the subject.

The first application of contingent measurement is the placement of subjects on an evaluative continuum. Bayroff and Seeley(1967)

at the U. S. Army Behavioral Research Laboratory did some of the
early work in the development and application of contingent mea-
surement procedures for the placement of subjects on verbal and
mathematical aptitude continua. They compared on-line contingent
tests and conventional paper-and-pencil tests with respect to
reliability, information conveyed by the test score, and test
construction rationale. For the study, Bayroff and Seeley con-
structed verbal ability and arithmetic reasoning branched tests
with items selected from the experimental forms of the Armed
Forces Qualification Tests, AFQT 7-8 and AFQT 5-6. The verbal
ability test was an 8 item test designed as a counterpart to
the traditional 40 item test in the Army Classification Battery;
the mathematical reasoning test was a 9 item test designed as a
counterpart for the traditional 50 item test. Each test plan
had a pool of items ranging in difficulty from $p=.25$ to $p=.95$.
Examinees who reached and successfully answered the most diffi-
cult item $p=.25$ were given an additional item of difficulty
$p=.20$ to increase the test ceiling. The four-alternative mul-
tiple choice items were expanded on the branched test to include
two additional wrong choices to reduce the chance of correct
guessing. The test item plan is shown in figure 2.

One hundred and two enlisted men from Fort Belvoir, Virginia
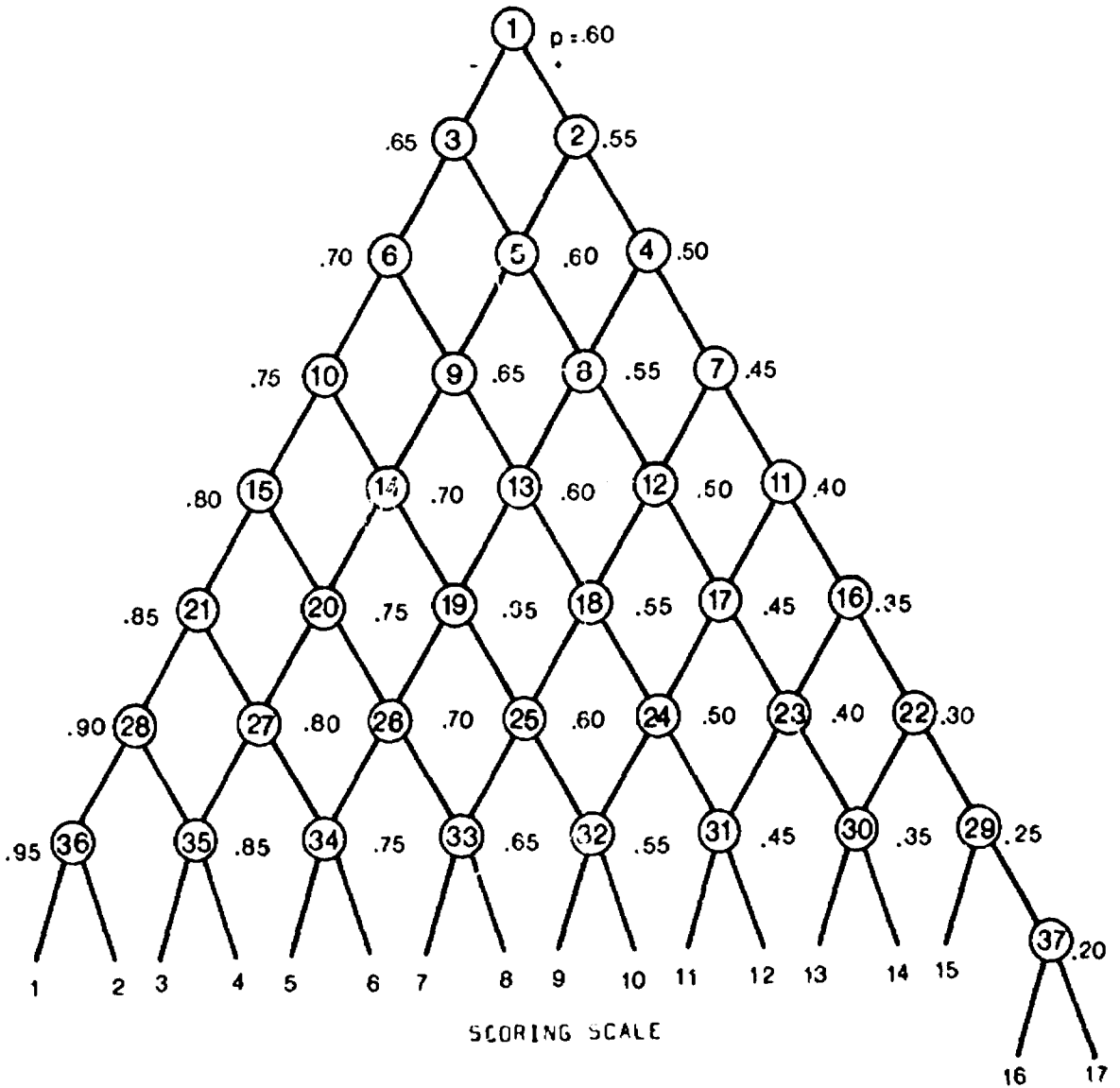took the two branched tests on the teletype and the two paper-

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Figure 2: Branching Test Plan for Contingent Measurement

and-pencil linear tests in counter-balanced order, half taking
the two branching tests first and half taking the two linear
tests first. The linear tests were scored in the traditional
manner and the branched tests were scored according to the
relative difficulty ratings of the last frame presented in the
test.

In analyzing the scores of the linear and contingent tests
Bayroff and Seeley found a correlation of r=.78 between the
verbal ability tests and .74 between the arithmetic reasoning
tests.

The test-retest reliabilities for the branched tests were
computed as r=.76 for the verbal and .73 for the arithmetic.
Since a previous study had established the test-retest relia-
bility of the linear verbal and arithmetic tests at r=.91 and
.85 respectively the reliabilities of the 8 and 9 item branched
tests were nearly the maximum that could reasonably be expected.
Using the Spearman-Brown formula, Bayroff and Seeley calculated
that a linear test would need 16 items to achieve the reliability
of the branched test for verbal ability and 19 items to achieve
the reliability of the branched test for arithmetic reasoning.

In this study Bayroff and Seeley have demonstrated empir-
ically the validity, reliability and time-saving feature of the
contingent procedure in placing subjects on the psychological

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continua of mathematical and verbal aptitudes.

The second application of contingent measurement programs
is the classification of subjects into supplies for description
or further research procedures. Traditional research designs
often call for matching of groups or homogeneous supplies of
subjects. The contingent measurement program can be used to
efficiently assess the matching characteristics of each subject
and assign subjects tracks on the basis of these characteristics.
After all the subjects have been contingently measured, those
following the same track can be used as matched subjects.

Ferguson (1970) developed and implemented one of the first
contingent tests for classifying students for placement in a
math curricula of individually prescribed instruction. Ferguson's
contingent test was designed to determine if the subject had or
had not mastered each of the 18 objectives in the Addition-
Subtraction math unit. Mastery or non-mastery for each objective
was assessed contingently by taking advantage of the Guttman-type
hierarchical task structure, figure 3, that was established among
the objectives in the unit. When a subject demonstrated mastery
of one of the objectives in the hierarchy the program inferred
mastery of all the objectives prerequisite to it.

Ferguson's contingent measurement program tested or inferred
the subject's mastery on each of the 18 objectives and classified
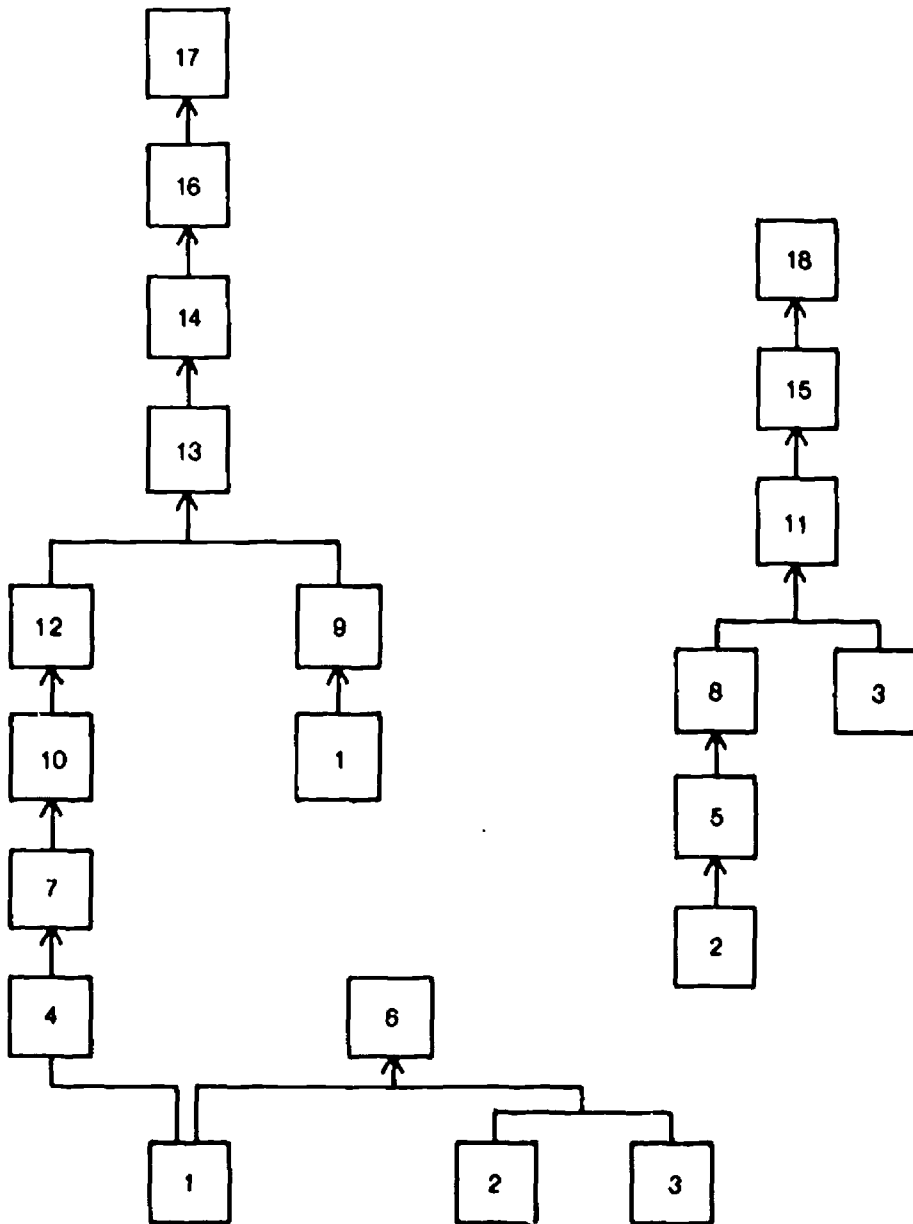the subject on the basis of the objectives for which he had

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Figure 3: Hierarchy for Addition-Subtraction Objectives

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demonstrated mastery. This classification was used to place

the subject at the appropriate place in the individually pre-

scribed instruction curriculum.

Ferguson's program made two types of contingent measurement

decisions:

1. whether a subject had or had not mastered a specific

   objective; and

2. what sequence of objectives should be tested for mastery.

The first type of decision, determination of proficiency

or non-proficiency in a specific objective, was made by presenting

randomly selected items of equal difficulty until the decision

algorithm had enough information to infer mastery or non-mastery

of that objective. The decision algorithm assumed that the

subject had the same probability of success on each item presented;

that the response to any given item was independent of the response

made to the previous item; and that the subject's score on the

items presented was an adequate estimate of his proficiency on

the objective.

Once a decision was made about the subject's proficiency

on one objective, a decision had to be made regarding the objec-

tive to be tested next. The task hierarchy in the Addition-

Subtraction unit was divided into the seven scales shown in

figure 4. Each scale is composed of a group of objectives which

are sequenced such that starting from the left, each objective

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is the prerequisite of all objectives to its right. The
branching algorithm for the sequencing of objectives used these
scales. Testing for all subjects began with objective 12 of
scale 1. If the subject demonstrated mastery of this objec-
tive he was branched to either objective 14 or 17 depending on
how many errors he had made in the set of frames presented for
objective 12. This branch and test cycle continued until a
decision had been made about each objective on the scale.

Scale	Objectives Comprising the Scale	Coefficient of Reproducibility for Scale
1	1, 4, 7, 10, 12, 13, 14, 16, 17	.995
2	1, 9, 13, 14, 16, 17	.992
3	1, 6	1.000
4	2, 6	.997
5	3, 6	.960
6	2, 5, 8, 11, 15, 18	.999
7	3, 11, 15, 18	1.000

Figure 4: Scales of Objectives for the Contingent Sequencing
Procedure

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The results of the branch and test cycle provided the in-
formation needed to place students at the appropriate point in
the math curriculum. It eliminated repetition of previously
learned objectives and ensured mastery of all necessary pre-
requisite material.

In some research situations the contingent procedure for
classification of subjects is longer and more difficult to
implement than traditional matching procedures. In each case,
the researcher must decide whether the adaptive testing fea-
tures and the high validity and reliability provided by the
contingent procedure merits the increased effort and time
required for implementation. In the study discussed, Ferguson
developed the testing program for incorporation into an aca-
demic curriculum. The continuing use of a contingent measure-
ment procedure to increase efficiency of a teaching sequence for
every student receiving a specific unit in mathmatics would seem
to merit the increased time required for development.

This contingent procedure is applicable wherever the researcher
needs to match subjects and can determine the relevant dimensions
for matching or wants to appropriately place subjects for further
research and can pinpoint the relevant criteria for placement.

The third application of contingent measurement programs is
the assignment of subjects to classes that are predictive of some
other variable of criterion status. Johnson (1969) did one of

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the first contingent measurement studies in which a subject's performance on a contingent task could be used to predict the subject's performance on a standardized test.

In his study Johnson gave the subjects a concept formation problem to solve. By making the solution to the problem contingent upon the subject's responses he was able to maximize trials to correct solution for each subject and thus maximize the information collected on each subject's concept formation process.

When Johnson analyzed the subjects' solutions he found that the subjects could be classified according to their solution methods.

1. Strategic group - characterized by methodical and predictable solutions.
   a. Scanners - a subset of the strategic group characterized by their taking many trials in a short period of time
   b. Focusers - a subset of the strategic group characterized by their taking a few trials in a long period of time
2. Tactical group - characterized by non-methodical and non-predictable solutions
3. Mixed Group - characterized by non-strategic and non-tactical solutions

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Johnson compared these three groups on SAT scores. He found
that the strategic group out-scored the tactical group by 50
points on the verbal test and 90 points on the math test. Within
the strategic group, the scanners and focusers performed the same
on the math test but the scanners performed 65 points better than
the focusers on the verbal test. By running subjects on this
contingent concept formation task and classifying them according
to their methods of problem solution, Johnson could use each
subject's classification to predict his SAT scores.

Johnson's research procedure does not provide the best method
for predicting a subject's SAT scores. However it does demon-
strate the use of a contingent procedure for assigning subjects
to classes that are predictive of another variable of criterion
status. Very little research has been done in this area of
contingent psychological research. The possibilities for this
method of prediction of variables are numerous.

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IV. SUMMARY AND CONCLUSIONS

        This study has focused on methods for the application of

on-line contingent research procedures to psychological task

management and parameter measurement. The new research designs

made available by the contingent stimulus presentation capability

are the primary advantage of the implementation of contingent

research procedure. These contingent designs enable the researcher

to apply treatments and collect data unavailable with traditional

research techniques. Concomitantly increased standardization

of research due to computer administration and the time-saving

feature of the contingent technique contribute to making the

on-line contingent research procedure an attractive alternative

to traditional research designs for some types of psychological

research.

        The success or failure of contingent research depends upon

the design of the program decision algorithm. Traditional research

procedures are designed to present the same predetermined sequence

of stimuli to all subjects within a treatment group and to make

no allowance for treatment-subject interaction. The variance in

the data resulting from treatment-subject interaction is usually

included as part of the error variance in the experiment. In

contrast, contingent research procedures are designed to present

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adaptive sequences of stimuli to each subject. By adapting
the stimuli presented the contingent procedure maximizes
treatment-subject interaction. Consequently traditional re-
search designs are incompatible with the goals of contingent
procedures. How then should the contingent programs be designed?
If the contingent procedure is to individualize the treatment
of each subject in a meaningful way each stimulus decision in
the contingent program must be established empirically and must
be tested for validity and reliability. By using a traditional
experimental design, the researcher must determine the treat-
ment-subject response patterns for all possible supplies of
subjects at each node of the contingent program and empirically
derive each branch. Contingencies cannot be developed by in-
tuition or guessing. Each contingency must be established in
the context of the program with the population for which the
program is designed. The value of contingent research data
rests on the assumption that the branches made within a program
for a given subject are meaningful and the contingent data
resulting from the program are in fact representative of the
subject. Establishing the contingencies is a time-consuming
tedious task but the comprehensive data produced by a sound
program provide the researcher information about treatment
effects, psychological processes, and treatment-subject

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interactions that is unavailable with traditional research
designs.

This study is in no way suggesting a complete switch from
traditional research procedures to contingent research procedures.
The traditional design is not only necessary in the establishment
of contingencies for the response contingent designs but it is
also an important research tool. A substantial portion of
psychological research is done well with traditional techniques
and contingencies have no meaningful place in the design. How-
ever, this study does suggest that for some types of research
the flexibility of the on-line contingent procedure will allow
the capability of performing valuable research previously impos-
sible to conduct with traditional techniques. Before imple-
menting the contingent procedure the researcher must assess the
relative advantages and disadvantages of the two procedures for
the goals and operations of his research. The addition rather
than substitution of the contingent procedure in the psycholog-
ical laboratory should provide the researcher a powerful combina-
tion of research procedures for more intensive and extensive
psychological research than was previously feasible.

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APPENDIX A

The multiplicity of shades of meaning assigned to the fol-
lowing terms in the literature necessitates the inclusion of the
precise definition used in this methodological analysis.

Algorithm: Webster's Seventh New Collegiate Dictionary defines

an algorithm as "a rule of procedure for solving a recurrent

mathematical problem". In contingent research an algorithm

is defined more specifically as a step by step procedure for

making program branching and stimulus presentation decisions.

The algorithm is the decision-making or logical component

of the contingent procedure developed by the researcher for

the computer and characterized by two properties:

1. It is deterministic in that it specifies an exact pro-

cedure to be followed at each step of the program.

2. It is general in that it specifies an exact procedure

for any and all subjects.

Branched Test: (Also called tailored test or sequential-item test)

A branched test presents each subject with only those ques-

tions that are most informative about his level of competence

in a specific skill or content area. The branched testing

technique achieves individuality by presenting an easier

item after each failure by the subject to respond correctly
and presenting a more difficult item after each successful
correct response. This process of stepping up and down the
difficulty scale theoretically seeks tne achievement level
of each subject.

The branched testing procedure was developed from the
psychophysical testing procedure by analogizing the question
difficulty scale to the stimulus intensity scale.

Contingent: Contingent refers to the characteristic of branching
on tne basis of a subject's immediate response, response
history or extra-program history.

History: (Also called history file) A history is recorded for
each subject run on a contingent program. The history pro-
vides a record of all intormation necessary in the program
decision making including:
1. the information initially entered in the computer on each
subject, for example, age, grade or sex.
2. the cumulative record ot all previous subject responses
on the program; and
3. the record ot all previous decisions made about the
subject on tne program.

On-line: On-line refers to the interactive computer as the pre-
    sentation mode of a program.

On-line Contingent Program: A generalized schematic of an on-line
    teaching program is drawn below. The features of this
    schematic are explained in the next four definitions.

START

Branch A   Branch B   Branch C

1 ────► 1A ────► 1B ────► 1C

2 ────► 2A ────► 2B ────► 2C

3 ────► 3A ────► 3B ────► 3C

4 ────► 4A ────► 4B ────► 4C
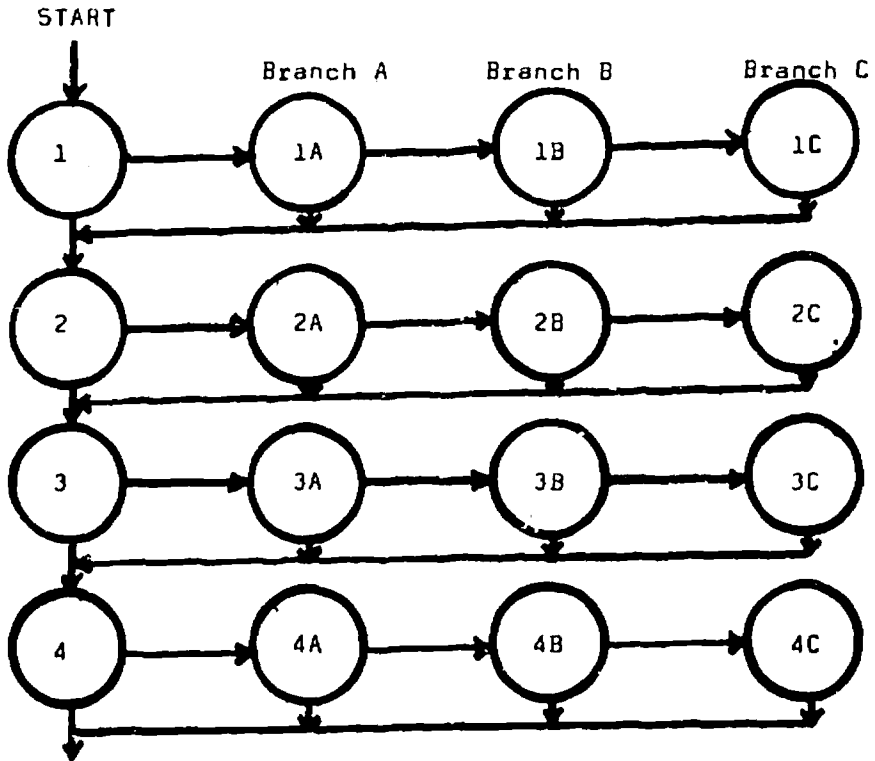
Mastery of Skill or Concept
        Being Taught

Figure 5: Generalized Schematic of an On-line Contingent
        Teaching Program

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Frame: A frame, the smallest component of an on-line contingent
    program, is defined as initiated when a decision is called
    for regarding which stimulus is to be presented next in the
    program and terminated when the history is updated with a
    record of the response made to that stimulus.

        In the schematic, groups of frames are represented
    rather than single frames. Nodes 1-4 on the unbranched
    track, nodes 1A-4C on the branched track and all the inter-
    nodal teaching sequences are groups of frames.

Node: A node is a decision point in a contingent program at which
    a subject may progress in one of two or more different direc-
    tions. In the schematic, the labeled circles represent the
    nodes. At each of these nodes the subject's responses to
    a series of frames determine on which of the two alternative
    paths he will proceed. For example, at node 1 the subject's
    responses determine whether he will progress vertically to
    node 2 (in the direction of mastery) or horizontally to
    branch 1A (for remedial work on the same level as the frames
    just completed).

Branch: A branch is a sequence of content and decision frames
    supplementary to the core sequence of content and decision
    frames. In the schematic of the teaching program, the

remedial teaching sequences and decision nodes extending

horizontally from the vertical linear path (nodes 1-4)

are branches. In contingent teaching programs a branch

is the vehicle for providing the student with adaptive

tutorial instruction based on his previous responses rather

than informing him simply of the correctness or incorrectness

of his responses.

Track: A track is the unique set of stimuli presented to a

specific subject in his progress through a contingent program.

A subject's track consists of each and every frame presented

to him from the initial stimulus to his terminal response.

In the schematic of the contingent learning program,

a subject's track would be designated by: each teaching frame

he received and his response to it; each nodal frame he

received and his response to it; and each program decision

made. From the schematic, it is evident that subjects may

follow any one of a large number of different tracks ranging

from the shortest (the vertical linear track) composed of

four teaching sequences and four nodes to the longest (the

horizontal branched track) composed of the entire vertical

track plus all the remedial teaching sequences and branch

nodes.

Strategy: The strategy of a contingent program is the logic of

the algorithmic decision procedure used to determine which

stimulus should be presented during each frame and to con-

trol the subject's track through the program.   It is assumed

that the computer has as data for the decision procedure:

all stimuli available for presentation or a complete set of

stimulus generation rules; the set of all responses permitted

by the subject; a complete set of branching decisions; and

a specified final performance criteria each subject is

expected to meet.   (Groen and Atkinson, 1966)

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