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ABSTRACT

The paper describes progress in the development of the Advanced Instructional System's Instructional Strategy Subsystem. Described are procedures for developing the Student Evaluation Component (which includes selection and validation of preassessment and within-course measures necessary for the development of a Student Data Profile) and the Adaptive Model Component (which includes selection and validation of instructional strategies and adaptive decision models, as well as the design and development of Resource Management/Scheduling and Incentive Management Models). The results indicate that the trait-state distinction and aptitude-by-treatment interaction methodology provide useful frameworks for the development of this subsystem. (Author)

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This paper describes progress in the development of the Advanced Instructional System's Instructional Strategy Subsystem. Described are procedures for developing the (a) Student Evaluation Component, which includes selection and validation of pre-assessment and within-course measures necessary for the development of a Student Data Profile; and (b) Adaptive Model Component, which includes selection and validation of instructional strategies and adaptive decision models, as well as the design and development of Resource Management/Scheduling and Incentive Management Models. Results indicate that the trait-state distinction and aptitude-by-treatment interaction methodology provide useful frameworks for the development of this subsystem.

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This paper describes the progress in the first phase of the design, development, implementation, and evaluation of the Student Evaluation and Adaptive Model Components of the Advanced Instructional System's (AIS) Instructional Strategy Subsystem. This description includes sections on the (a) selection and validation of pre-assessment and within-course measures for each AIS course, (b) design and development of a Student Data Profile of relevant student characteristic variables in each course, (c) selection and validation of instructional strategies and adaptive instructional decision models for individualizing student prescriptions in each course; (d) design and development of the Resource Management/Scheduling Model for insuring effective and efficient assignment of students to AIS resources, and (e) design and development of an Incentive Management Model for improving student motivation and performance in each AIS course.

The design goals of the Student Evaluation Component are (1) to identify those student characteristics and their associated measurement instruments which best describe the nature of the student population in each course with respect to their performance and training times, and

(2) to select the procedure for classifying this student information which maximizes the efficiency of the Adaptive Models for individualizing the instructional process. A theory which provides a conceptual framework for meeting these goals is Cattell's (1957) trait-state theory. This theory clarifies the distinction between traits (relatively stable individual difference variables) and states (transitory individual difference variables which are influenced by changing situational factors), and provides the basis for a classification of student characteristics. Within AIS, the trait variables are considered to be the static cognitive and affective variables measured as a result of pre-assessment testing; the state variables are considered to be the dynamic cognitive and affective variables measured as a result of within-course testing. This trait-state; static - dynamic distinction allows for the partitioning of the Student Data Profile such that various classes of variables are given greater or lessor importance in adaptive model decisions, dependent on their expected and/or empirical relationships to performance and training time scores in each course. It is expected that trait variables will be of most importance in performance predictions for early course blocks, whereas state variables will be of most importance in subsequent within-course predictions.

The design goals of the Adaptive Models Component are (1) to develop instructional alternatives or strategies within each course that best meet the differential needs and capabilities of each student, and (2) to automate the selection of effective instructional strategies via computer-based models which take these differential student characteristics into account in the selection of each alternative. The conceptual framework which best fits the design goals of this component is the Aptitude-by-Treatment Interaction (ATI) approach and methodology. The ATI approach is based on the assumption that, given a single set of desirable educational outcomes and several methods for achieving these outcomes, aptitude or other individual difference variables will be able to predict the method most predictive of individual success in obtaining these desired outcomes (Cronbach & Snow, In Press). Within AIS, the desired outcomes are increased student performance and motivation, and decreased training time; the alternate methods for achieving these outcomes are the instructional strategies in each course. Since the ATI methodology is aimed at adapting instruction to individual student needs, the basis for deciding which of several alternative strategies will maximize AIS outcomes depends on the detection of valid and reliable ATIs. The detection of these ATIs then forms an empirical basis for deriving adaptive decision models and rules.

Student Evaluation Component

Selection and Validation of Pre-assessment and Within-Course Measures. The selection of a pre-assessment battery for each course was based on (1) instructor interview data with respect to their assessment of which student characteristics were related to success and failure in their respective courses, (2) analyses of the nature of the instructional content and types of learning required for each lesson, and (3) reviews of the educational/psychological literature to determine the best available instruments for measuring the student traits identified. The selection of appropriate within-course measures was based on an analysis and empirical review of existing state measures that could provide an assessment of students' changes in affect or learning as a function of the AIS materials in each course. In the cases where no previously developed standardized instruments could be identified for measuring these relevant variables, customized measures were developed. All tests selected were those which assessed the cognitive and affective traits and states felt to be most related to student performance, motivation, and training time in each course.

The selected pre-assessment batteries are administered to students at the beginning of each course by Air Force instructors who have been trained in a standardized test administration procedure. To further standardize test administration procedures, an audio-tape of instructions to the student was prepared for use during pre-assessment testing. Pre-assessment tests in each course are given in three groups. Group One consists of time cognitive trait measures which include standardized reasoning tests and hidden figures tests; plus specially developed tests of reading ability (comprehension and speed) for each course (McCombs, 1974), a specialized reading vocabulary test (Deignan, 1973), a memory for numbers test for the Inventory Management/Materials Facilities courses (Siering, 1974), and an associative memory test for the Weapons Mechanic course (Siering, 1974). Group Two consists of a course-specific affective trait measure of students' expected feelings of curiosity and anxiety while learning their respective course materials (Leherissey, 1971; Spielberger, Gorsuch, & Lushene, 1970). Group Three consists of affective trait measures which are untimed and which include a general trait curiosity and anxiety scale (Day, 1969; Spielberger et al., 1970), the Internal-External Scale (Rotter, 1966), the Test Taking Attitude Scale (Sarason, 1958), the Delta Biographical Scale (Deignan, 1974), and a General Media

Preference Scale to assess student preferences for various modes of learning AIS materials (McCombs, 1974).

The selected within-course measures were assembled in a series of folders which are periodically administered by trained Air Force instructors to each student as he progresses through each block of AIS materials. The first folder contains a pre-lesson interest scale to assess his expected feelings of curiosity and anxiety toward the first lesson materials in that block (Leherissey, 1971; Spielberger et al., 1970). Succeeding folders within the block consist of other pre-lesson interest scales to assess expected feelings for the next set of lesson materials. The folder following the last lesson in the block consists of a pre-Specific Test Taking Attitude Scale (modified from Spielberger et al., 1970). After the student finishes his end-of-block test, he is given a final folder which contains the Specific Media Preference Scale (McCombs, 1974) to assess how he felt about the various media he used in the block, and the Attitude Toward Instructional Method Scale (McCombs, 1974) to assess his feelings about the instructional materials and strategies used in the block. Criterion measurement within each block consists of multiple-choice and performance lesson tests and the end-of-block test constructed by the Instructional Materials Subsystem, and times-to-complete each lesson and block. The affective within-course measures were used not only as predictors of within-course performance, but also as measures of the effectiveness of the instructional materials.

Pre-assessment Testing Results. Data analysis of the pre-assessment data is conducted in several steps. The first step is to calculate a measure of internal consistency, the alpha reliability coefficient, on all scales in each battery. The item data is then used to revise measures with low total and item remainder correlations. In general, scale reliabilities were moderate to high in each battery (.58 to .91) prior to their initial revisions. In addition to achieving reliability information, the scales in question are intercorrelated and factor analyzed. This provides information on the statistical redundancy of predictors. As a last step, stepwise regression is used to select possible predictors of student performance in each course. Criterion data for this set of analyses includes block test scores and time-to-complete the block.

Preliminary stepwise regression analysis data from the Inventory Management (IM) course indicates that the Delta Reading Vocabulary Test (Deignan, 1974), the Memory for Numbers (Forward Subscale) Test (Siering, 1974), the Logical Reasoning Test (Hertzka & Guilford, 1955), IM/MF Reading Skills Scale (McCombs, 1974), Test Taking Attitude Scale (Sarason, 1958), and the General Media Preference Scale (McCombs, 1974) were the best predictors of end-of-block scores for Block V of this course (n = 269, multiple r = .54). For this same course and block, the best predictors of time-to-complete the block were the Delta Reading Vocabulary Test, Memory for Numbers (Forward Subscale) Test, General Media Preference Scale, Logical Reasoning Test, Sex, Pre-Course State Curiosity (McCombs, 1974), and the IM/MF Reading Skills Scale (n = 269, multiple r = .43). Results of additional stepwise regression analyses calculated on each lesson in Block V of the IM course indicate that differential pre-assessment measures predict the ten lesson scores and times (multiple r's ranged from .33 to .54 for scores, and from .19 to .43 for times, with an n = 244).

In the Materials Facilities (MF) course, preliminary data from Block V stepwise regression analyses indicates that the IM/MF Reading Skills

Scale, Memory for Numbers (Backward Subscale) Test, Logical Reasoning Test, General Media Preference Scale, and Trait Anxiety Scale (Spielberger et al., 1970) were the best predictors of end-of-block score (n = 122, multiple r = .60). The best predictors of time-to-complete Block V of the MF course were the IM/MF Reading Skills Scale, General Media Preference Scale, Delta Reading Vocabulary Test, Trait Curiosity Scale (Day, 1969), Concealed Figures Test (Deignan, 1974), Pre-Course State Curiosity, and Sex (n = 122, multiple r = .59). Results of additional stepwise regression analyses calculated on each lesson in Block V of the MF course also indicate that differential pre-assessment measures predict the nine lesson scores and times (multiple r's ranged from .32 to .60 for scores, and from .34 to .42 for times, with an n = 122).

In general, the present data indicate that the majority of the measures in the pre-assessment testing battery for the IM and MF courses predict either block and lesson scores or block and lesson times for the respective Block V's of these two courses. Decisions as to revising the present pre-assessment batteries for these two AIS courses to include only those measures which do predict the criterion variables of interest must necessarily await the analysis of the relationships of these measures with the criterion variables for each block when the entire course is self-paced. These subsequent analyses will also provide a cross-validation of the preliminary results reported above.

Within-Course Testing Results. Data analysis of the within-course testing data is also conducted in several steps. The first step is to calculate alpha reliability coefficients on all multiple-choice affective and cognitive measures. For affective measures, moderate to high scale reliabilities were found (.66 to .93), and where low total or item remainder correlations were found, the scales in question were revised. For cognitive measures (lesson tests and end-of-block tests), those tests which demonstrated low internal consistencies were identified to the Instructional Materials Subsystem for revision. Intercorrelations between the affective and cognitive tests are calculated following necessary revisions, and stepwise regression is used to select possible predictors of student performance in each block.

Results of preliminary intercorrelations of within-course measures in the two Block V's of the IM and MF courses indicate that differential lesson scores are related to end-of-block scores (r's ranged from .28 to .62, $p < .05$), and times-to-complete differential lessons (r's ranged from -.28 to -.45, $p < .05$). In addition, state curiosity was related to Block V scores for MF students (r's ranged from -.32 to -.49, $p < .05$). Time-to-complete Block V of the MF course was related to differential lesson scores (r's ranged from -.24 to -.46, $p < .05$), times-to-complete differential lessons (r's ranged from .31 to .70, $p < .05$), and state curiosity (r's ranged from .31 to -.31, $p < .05$). The correlations of periodic state anxiety and state curiosity measures given within the two Block V's indicate that both state anxiety and state curiosity are related to subsequent lesson scores and times at differential points in the block (r's ranged from -.32 to .36, $p < .05$), and that differential lesson scores and times are related to subsequent lesson scores and times (r's ranged from -.47 to .66, $p < .05$). Those affective measurement points which did not yield significant correlations were dropped, leaving only those measures that did contribute to the prediction of lesson or block times and scores.

In a preliminary stepwise regression analysis calculated on the end-of-block scores for Block V of the IM course, the following within-course measures best predicted the block score: Lesson 7 score, Lesson 3 score, Lesson 9 score, Lesson 6 score, Lesson 1 score, Lesson 10 score, and the pre block test state anxiety measure ($n = 244$, multiple $r = .61$). The best predictors of time-to-complete Block V of the IM course were Lesson 9 time, Lesson 2 time, pre Lesson 1 state anxiety, Lesson 6 time, and the pre block test state anxiety measure ($n = 244$; multiple $r = .55$).

A similar preliminary stepwise regression analysis calculated on the end-of-block scores for Block V of the MF course indicates that the best within-course predictors of block score were Lesson 1 score, Lesson 5 score, Lesson 3 score, Lesson 7 score, after Lesson 4 state curiosity, Lesson 4 score, after Lesson 4 state anxiety, and Lesson 9 score ($n = 78$, multiple $r = .79$). The best within-course predictors of time-to-complete Block V of the MF course were Lesson 2 time, Lesson 8 time, after Lesson 4 state anxiety, Lesson 6 time, after Lesson 9 state curiosity, Lesson 4 time, Lesson 5 time, sex, after Lesson 4 state curiosity, and Lesson 3 time ($n = 78$, multiple $r = .81$).

All within-course affective scales in the three AIS courses have recently been revised to include only those items which had the highest item-remainder correlations, resulting in the reduction of items per scale from 20 to 10 and in the construction of different scale items for the various administrations within each block and course. In addition, the scales have been reformatted to include lesson-specific introductions for the pre lesson scales, and the items have been re-ordered for each administration. These procedures are expected to enhance the predictibility of the affective within-course measures. Analysis of the predictibility of these revised scales shall begin in May 1975, after sufficient student data has been collected.

Design and Development of Student Data Profile. The design of the Student Data Profile for each course is based on the results of pre-assessment and within-course test validations and the classification of these student variables in terms of trait and state, cognitive and affective student characteristics. Those state and trait variables which are found to be predictors of student performance and training time shall be differentially weighted in the prediction equations which operate off this profile. This results, eventually, in a reduced set of variables to be retained in the Student Data Profile as input (decision factors) to the adaptive decision rules and prediction equations.

Adaptive Model Component

Selection and Validation of Instructional Strategies and Adaptive Instructional Decision Models. The initial selection of instructional strategies for each course was based on (1) instructor interview data with respect to their assessment of the most effective methods for teaching various kinds of students in their respective courses, (2) course analysis data on the types of learning objectives, relative difficulty levels, and suggested media for each lesson, and (3) selective research data suggestive of possible ATIs with comparable student populations and instructional materials. An Instructional Alternatives Identification Chart was then prepared to serve as a guide in identifying those strategies which might prove most effective and worthy of investigation in each course. The final selection of alternative strategies for implementation is to be based primarily on the student performance and time data collected during formative evaluations of each AIS course materials. Those lessons for which selected student characteristic variables clearly predict student performance and time scores shall be further analyzed in terms of the best instructional strategy alternative matches, and strategies shall be selected which yield the best fit of student characteristics and instructional content variables. Lesson difficulty data, in terms of greatest ranges of student time and performance scores, will also form a basis for selecting CAI, multi-tracking, and media overlap strategies.

In order not to interfere with the initial development of one-track of mainline instruction, it was necessary to choose initial strategy alternatives which would not interfere with materials or media development and would not involve the production of vastly different alternative material packages for the same lesson. Furthermore, the initial alternative strategies chosen were those which could help answer questions to guide material and media development, could provide formative pilot data on instructional strategy validation procedures, as well as provide valuable information on the most viable forms of decision rules for the Adaptive Models. These initial alternative included various frequencies of testing strategies, comparisons of printed and mediated lesson materials, and selected intrinsic incentive strategies described in a subsequent section of this paper. The later investigation of more substantive instructional strategy alternatives must necessarily await the analysis of this preliminary pilot data, the development of multi-tracking, media overlap, and CAI materials, and the development of the Adaptive Models capability.

Instructional strategy validation procedures shall consist of assigning entire classes of students entering each new AIS block of materials to particular instructional alternatives for a predetermined measurement period, such that at least 100 students go through each alternative.

The general approach will be to find and replicate main effects and ATIs. Reliable main effect information shall be communicated to instructional designers for use in material construction; reliable ATI information is to be used in the development of preliminary decision rules for assigning particular kinds of students to particular instructional alternatives. A general revalidation of these effects shall then be conducted and all prediction equations updated prior to the development of decision rules to be implemented in the initial Adaptive Model.

Design considerations for the Adaptive Instructional Decision Models include the necessity for an evolutionary and iterative process of continual updating, extension, and refinement of the models in order to converge on an effective set of decision rules for individualizing instruction in each course. Through successive iterations, simple-to-complex decision models are to be implemented and evaluated on the basis of student performance, training time, and affective data. The first Adaptive Model iteration, planned for implementation in August 1975, shall incorporate the validated decision rules resulting from instructional strategy validation data within the first AIS course.

Detailed specifications of the capabilities of the first Adaptive Model iteration have been completed and coordinated with personnel in the AIS Software Subsystem. These capabilities include four adaptive off-line testing models: (1) and Adaptive Frequency of Testing Model for determining how frequently to test each student as he progresses through each AIS block; (2) a Criterion-Zone Block Testing Model for more accurately assessing the fail status of students just below the criterion score on each AIS block test; (3) a Student-Option Pretesting Model for allowing students to choose whether to pretest out of particular lessons in each AIS block; and (4) a Critical Objective Retesting Model for periodically and differentially retesting and assessing student retention of objectives specified as critical by the technical experts in each course.

In addition to these four off-line testing models, four adaptive alternative selection models have been designed for implementation and validation in the first Adaptive Model iteration. These selection models are based on predictive statistical modeling methodology and include (1) the Full Regression Selection Models which take into account the full set of student variables (pre-assessment and within-course measures of both organismic and response variables) most predictive of time or performance scores when making alternative strategy decisions for selected AIS lessons; (2) the ATI Selection Models which operate with a restricted set of student variables (pre-assessment and within-course measures of organismic variables) for which alternative treatments were designed and validated when making alternative strategy decisions for selected lessons; (3) a Random Selection Model which assigns random weights to each alternative treatment within a lesson so that evaluation and update of the Adaptive Selection Models are facilitated; and (4) a Remedial Selection Model which selects adaptive remedial assignments for students who have failed a module or lesson assignment.

Additional portions of the Adaptive Models specification include a detailed flow chart and description of alternative instructional strategies development and validation procedures, as well as Adaptive Selection Models validation and update procedures. Also defined are the model approach, implementation approach (including advantages and feasibility), interface between the adaptive alternative selection procedures and the

Resource Management/Scheduling Model, software implementation, database definitions, and interface requirements with other AIS components. The actual development of the software for the initial Adaptive Model is currently in pregress.

Design and Development of Resource Management/Scheduling Model

Design requirements for this model include the capability for representing the course hierarchy of each course as a network with incorporates the condidtional sequencing relationships existing between each node. The model must also make provisions for taking into consideration the characteristics of the students being managed and the dynamic schedules of all other students in the network when making resource decisions which maximize the efficiency of each course. The design of the Resource Management/ Scheduling Model includes a description of the interface between this model and the Adaptive Instructional Models such that each resource decision takes into account the best instructional strategy alternatives for each student. This is accomplished via a compromise function that differentially weights the adaptive selection model preferences and the resource allocation model preferences.

As an initial step in the development of this model, detailed data from each course was collected with respect to course hierarchy information, resource requirements for each lesson, resource availability, and student flow information. This data has been incorporated into a simulation model of the first AIS course and valuable data is being collected on potential resource bottlenecks and student queing problems. Actual student performance data from the instructional strategy validations will be fed into the simulation and results fed back to the instructional materials design team to assist them in the identification of lessons for multi-tracking and media overlap that would improve the overall efficiency of resource management and scheduling. An initial version of this model shall be ready for implementation with the first Adaptive Model iteration.

Design and Development of Incentive Management Model

Two major objectives in the design and development of the incentive management model are to (a) identify student subgroups for whom specified incentive strategies are differentially performance-effective and (b) determine the effects of intrinsic vs. extrinsic incentives upon student performance given varying task requirement levels. To this end, a programmatic investigation of incentive management treatments shall include: (1) Goal Setting - Students predict their individual lesson scores within each block. Actual test scores after each test will be provided to the student prior to initiation of work on the subsequent lesson. Variations of this treatment include time-to-complete lesson predictions and both achievement and time-to-complete predictions. (2) Contingency Management - Students are informed that a specified number of points will be added to their end-of-block scores if their lesson performance meets or exceeds the average lesson test scores of a student reference group. As in (1), time-to-complete and both achievement and time-to-complete contingencies will be studied. (3) Performance Contracting - Bonus points are added to the student's end-of-block scores to the extent that formally contracted goals are met or exceeded. Various levels of contracting shall again be studied (achievement only, time-to-complete only, both achievement and time-to-complete), as well as levels of student committment (passive vs. required).

To ensure measurement of student expectancies, incentive attractiveness shall be measured prior and subsequent to treatment conditions. Measures of subjective probability of task accomplishment and reward expectancy will also be given. Student performance levels shall be analyzed with respect to pre-assessment and student expectancy measures. Regression analyses will be calculated to determine the relationships among incentive strategy conditions and student performance levels subgrouped on the basis of student characteristics and expectancies. Data from such analyses permit an individualized tailoring of instructional strategies once cross-validation of relationships ensures stability. The investigation of this preliminary incentive management system is planned to begin in June 1975.

Results and Conclusions

Considerable progress has been made in the (a) identification of reliable and effective measures and predictors of student characteristics and performance in the first AIS course and (b) identification of potentially effective and reliable instructional strategies and in the development of the Adaptive Instructional Models, Resource Management/Scheduling Model, and Incentive Management Model. Of particular importance in terms of educational implications is the demonstration of the trait-state distinction and ATI methodology in an operational setting, and the integration of these methodologies in the design and development of a computer-based Adaptive Model for individualizing the instructional process.

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