AD-752 634

STRATEGIC DISPOSITION TESTS AND THE INFLUENCE OF LEARNING STRATEGY ON THE PERFORMANCE AND BREAKDOWN OF SKILLS

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System Research Ltd

Prepared for:

Air Force Office of Scientific Research

3 November 1972

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U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

AFOSR - TR - 72 - 2233

3 NOV 1972

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INTERIM SCIENTIFIC REPORT

Strategic disposition tests and the influence of learning strategy on the performance and breakdown of skills

F44620-72-C-0091

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B.C.E. Scott

May 1st 1972 - October 31st 1972

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Telephones: 940 0801

21

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) System Research Ltd 2 Richmond Hill Richmond, Surrey, Uk	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

STRATEGIC DISPOSITION TESTS AND THE INFLUENCE OF LEARNING STRATEGY ON THE PERFORMANCE AND BREAKDOWN OF SKILLS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific Interim

5. AUTHOR(S) (First name, middle initial, last name)

Gordon Pask, M.A., Ph.D.

6. REPORT DATE 3 Nov 72	7a. TOTAL NO. OF PAGES ~~15~~ 21	7b. NO. OF REFS 10
8a. CONTRACT OR GRANT NO. F44620-72-C-0091 b. PROJECT NO. 9778 c. 61102F d. 681313	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR - TR - 72 - 2233	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY AF Office of Scientific Research/NL Arlington, Virginia 22209

13. ABSTRACT

Progress on two projects is described: Project A: to develop strategic disposition tests for determining individual competance and preferred learning style; Project B: to examine relationships between individual competence on a task under conditions of stress as a function of type of training. Project A: Subjects were given a battery of questionnaires and aptitude tests to classify them as either "holists" or "serialists". A holist is one who attacks a learning task simultaneously from several aspects. He sets himself multiple subgoals and learns about several topics at once. A serialist sets himself the subgoal of learning about one topic at a time, and will only proceed to a further topic when that subgoal has been fully achieved. Holists and serialists are then given learning tasks and their success compared. Project B: Serialists and Holists are given a task simulating the role of the operator of a ground missile site. They are presented with data on airborne objects: altitude, speed, range, azimuth, etc. as well as characteristics of the defensive missiles: range, number available, reloading times. Stress is introduced by increasing the number and frequency of invaders. Subjects must assess the threats posed by the targets and make decisions on when and whether to fire their missiles. The performance of Holists vs. serialists is assessed, as well as they operating procedures when stressed. The holist tends to make decisions based on multiple parameters, with often a high uncertainity factor for each parameter. The serialist poses specific hypotheses and reduces his uncertainty about the values of single variables, before proceeding to pose hypotheses about target type and action to take. The holist tends to over-generalize; while the serialist is less flexible in an overload or stress condition.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Learning						
Missiles						
holist						
serialist						
stress						

Interim Scientific Report

Project Title: Strategic disposition tests and the influence of learning strategy on the performance and breakdown of skills.

Contract No. F44620-72-C-0091

Principal Investigator: Gordon Pask, M.A., Ph.D.

Reporting Period: May 1st 1972 - October 31st 1972.

1. Introduction.

The main effort during the reporting period has been focussed on Projects A and B of the research proposal. The aim of Project A is to develop strategic disposition tests for determining individual competance and preferred learning style. The aim of Project B is to examine the relationships between individual competence and performance on a task under conditions of stress as a function of type of training.

Work on project A is detailed in Section 2. A pre-test battery of representative aptitude tests has been assembled. These have been gathered mainly from existing tests and discriminating instruments. The intention is to examine the degree to which the holist-serialist distinction of learning types (stated more fully in the research proposal and in Section 2) is complemented by and correlated with distinctions made by other workers in the field of individual differences.

The data bases and question cards for the tests for strategic disposition have been prepared. The equipment for recording strategy adopted and testing the students competence has been assembled. Pilot experiments are in progress utilizing the equipment and one of the data bases: the learning of a classification scheme. Preliminary results are presented in Section 2.

Work on project B is detailed in Section 3. The task that subjects are required to perform under conditions of stress has been designed; it simulates the role of the operator of an anti-missile, anti-aircraft system. The operator has the task of detecting and computing the positions and intentions of enemy craft and of carrying out the necessary computation and decision-making for dealing with the intruder effectively. The design for the equipment and the recording facilities for this simulated task have been recently completed and construction has been initiated. The design of the apparatus has necessarily involved the specification of detailed hypotheses about the sorts of performance expected of holist and serialist type learners under stress conditions.

2. Project A.

The test instrument of Project A is designed to discriminate between individuals in terms of their learning strategy. The main distinction is between individuals who adopt a serialist strategy and those who adopt a holist strategy. Briefly, a serialist is characterised by a "one step at once" approach to the learning task. He sets himself the subgoal of learning about one particular topic or aspect of the task and will only proceed to a further topic or aspect when that subgoal has been fully achieved. Restated in terms of the cognitive controls for directing attention to particular topics, a serialist student typically has but one locus of control: there is only one relation in his environment that he attempts to learn about on any one occasion.

By contrast, a holist is characterised by a "global" approach to the learning task. He sets himself multiple subgoals and learns about several topics or aspects of the task at once. He thus has several loci of control: there are several relations in his environment that he attempts to learn about on any one occasion; in doing so he necessarily looks for and learns about higher-order relations, that is relations between relations; he will look for ways in which the various topics he is learning can be related together in terms of analogies, similarities, symmetries and so on. In doing so, he is prone to pose complex hypotheses about the subject matter and to generalise wherever possible.

A second distinction is to be examined. This looks at an individuals versatility. The holist-serialist distinction is seen as a difference in "built-in" competence. To the extent that a learner is aware of his built in limitations he can show versatility in approaching different tasks by augmenting his given cognitive competence. Two indicators of versatility are receiving attention:

1. the degree to which an individual plans his course of action and
2. the use made of facilities, such as note-taking and the generation of charts and diagrams.

2.1. Pre-test Battery

A battery of questionaires and aptitude tests of the paper and pencil type has been assembled.

The intention is to see what extent the holist-serialist distinction is correlated with distinctions mooted by other investigators, thus the majority of the tests have been culled from standard sources. The tests in question are of the following kinds:

1. Ananalogies completion test.
2. A test of logical reasoning using "nonsense" syllogisms.
3. A speed test for perceptual discrimination.
4. An "embedded figures" test that examines the distinction "field dependent - field independent" (Witkin).
5. A test of rigidity of problem-solving "set" based on the Luchin's water jars problems.

6. A test for "divergent" thinking known as the "circles test". The test is of the open-ended kind; the testee has to produce as many drawings of objects he can that are based on a circle shape.
7. A test that examines the distinction "reflective-impulsive" (Kagan).
8. An "essay" test: testees are asked to generate a description, in essay form, of a situation presented pictorially for a brief interval.

A standard questionaire asks the student to state information about his career, interests, hobbies, and academic background.

2.2. The Strategic disposition test data bases

The tests for strategic disposition in all cases require the testee to learn a small but complex body of knowledge - usually ½hr. to 1hr. learning time is required.

The data bases for the tasks take the form of indexed cards, each of which carries information about a particular topic in the subject matter. Associated with the data base is a graphical representation of the relations that exist between the topics; such a graph is called an "entailment structure"; it represents what may be known and the ways in which learning a particular topic entails prior learning of other topics, i.e. the graph represents a partial ordering over topics and depicts the possible routes a learner can take in finding out about the subject matter.

For each data base and entailment structure a set of multiple-choice question cards exists, which test for knowlege of topics and their relations. These cards are punch coded for use with the BOSS system (Belief and Opinion Sampling System) described in detail in the research proposal. Boss is a confidence estimation device that measures a testee's subjective uncertainty over the alternative answers presented on the multiple-choice card. The incorrect alternatives (there is always just <u>one</u> correct answer) are obtained by taking each topic in turn and generating answers that the testee would find plausible if he was ignorant of one or more of the entailed topics.

Data bases, entailment structures and BOSS question cards exist for the following subject matters:
1. a classification scheme for a fictional species of Martian animal
2. the systemic features of a cyclic biological process: the "operon cycle" and 3. simple probabilistic inference.

2.3. Strategic disposition test format

The data bases and question sets are used for two test situations. One situation requires the student to learn the subject matter in a "free learning" mode: the student regards the set of indexed data cards as a "library" and freely chooses what card or cards to attend to on a particular occasion. The second situation requires the student to learn the subject matter by attending to the indexed data cards in a prescribed order, as in a standard linear programmed text. In the former situation the main catagories of topics and their relations are displayed to the student on a chart in the latter situation no chart is displayed. In both situations BOSS testing takes place during and after the learning session.

2.3.1. The Free-Learning test situation

In outline, the free-learning test situation is as follows: the main index of strategic disposition is the series of decisions the testee makes when selecting cards from the library. Card(s) are only made available to the testee in response to questions. The testee must state what information he is seeking and classify his request as being one of the following:

1. an exploratory perusal of the categories of information available.
2. a general search for relevant items of information.
3. a request for the answer to a specific question.
4. a request for the answers to a complex.
5. to test a specific hypothesis.
6. to test a complex hypothesis.

The term "specific" refers to questions and hypotheses that requires access to only one index card. "Complex" refers to questions and hypotheses that require access to more than one index card.

Mechanical recordings are made of the testee's question types, their order and the number of cards requested on any one occasion.

Other recordings concern the extent to which a testee makes notes and the uses to which they are put.

2.3.2. Pilot Experiments

Currently pilot experiments using the classification task are being conducted. 10 subjects have been run in informal sessions to ensure the cogency of the test design and to determine the following: (1) the optimum form of briefing so that the testee is properly orientated to the task (2) the optimum occasions for BOSS testing (3) the time constraints to be imposed before a testee has to return any cards accessed and/or restate his question and (4) the minimum time required for a session to provide a reliable index of his strategic disposition.

The results so far show that a 1 hour session, includingbriefing, is sufficient to classify a student as holist or serialist using the indexes "number of cards accessed on an occasion" and "specificity or complexity of questions and hypotheses". A holist typically requests several cards

	Subject No.	Mean No. of cards per occasion	Frequency of question catagories (1 - 6)						Total No. of Questions
			1	2	3	4	5	6	
Holist Subjects	1	4.2	1	2	2	6	4	10	25
	2	5.6	0	0	5	15	6	9	35
	3	3.8	0	0	3	10	6	12	31
	4	3.0	1	4	4	8	6	12	34
	5	3.2	2	1	7	9	2	10	39
Means		4.1	0.8	1.4	4.2	9.6	4.8	10.6	32.8
S.D's		1.0	0.8	1.7	2.0	3.3	2.7	2.7	5.2
Serialist Subjects	6	1.0	1	10	20	0	2	0	33
	7	1.3	2	0	25	1	4	0	32
	8	2.1	1	7	16	2	18	1	45
	9	2.0	1	4	12	3	10	0	30
	10	1.8	0	3	30	1	2	0	36
Means		1.6	1	4.8	20.6	1.4	7.2	0.2	35.2
S.D'S		0.5	0.7	3.8	7.1	1.1	6.9	0.5	5.9

Table 1. Summary of data for pilot experiments of Project A.

at once and asks complex questions and tests complex hypotheses. A serialist typically requests one or two cards and asks simple questions and tests simple hypotheses.

The subjects used were students, age-range 20-25, known to the experimenter. They were selected on the basis of prior knowledge of their general learning style so as to give a sample of 5 holists and 5 serialists. Summary data is shown in table 1.

2.3.3. "Prescribed Order" testing situation

The prescribed order testing situation uses the data base index cards arranged in a prescribed order as in a programmed text. The testee has to go through the text card by card, answering simple "fill in the blank" questions on each card. For each data base two orders of presentation have been prescribed: one is designed to suit a holist the other a serialist learner.

The test situation has two purposes. The first is to check the reliability of free-learning classifications: the main prediction is that a learner classified as a serialist and presented with a holist programme will have great difficulty learning and vice versa. Informal sessions using the subjects classified in the free-learning situation are to be initiated shortly to determine the optimum procedure for the study.

The second purpose is to examine the reliability with which and conditions in which programmed texts can serve as discriminators of strategic disposition. For some purposes such a test would be a more conveniently administered alternative to the free-learning situation. The usefulness of the prescribed order texts is likely to be limited by the versatility factor mentioned in Section 2 (above) which would blur distinctions and by the difficulty of designing a text which can be guaranteed to be impossible for a holist learner since it is likely that given enough exposure to a serialist type text a holist is able to discover the kinds of high-order relations he prefers. Careful monitoring of time spent going through the text is required in such cases. Despite these limitations, there exists the real possibility of using a simple prescribed order learning task to detect non-versatile serialists. It seems likely that such a learner would find it virtually impossible to learn from a text designed for a holist.

2.3.4. Classification of Strategic Disposition by Factor Analysis.

Following discussions at Wrightfield, it is planned to treat the data by factor analytic methods, such as those of Shepard (1962a,1962b), Bealsetal (1968) and Kruskal (1964a, 1964b). When problems have been explored further, it is proposed that Dr. Pask, Mr. Scott and Mr. Kallikourdis visit both Washington and Wrightfield in early 1973 for discussion of the possible fruitfulness of the approach. It is hoped also to present initial results from Project B.

3. Project B

The simulated task of Project B is designed to investigate the form of task breakdown under load induced stress, with particular emphasis upon an individual's ability to "fall back" upon previously learned modes of performance. The two major independent variables are (1) mode of training and (11) strategic disposition. Training will be of two kinds (1) standard training in operating procedures which does not consider an individual's strategic disposition (11) "conversational" training that does take into account the strategic disposition of the learner. Strategic disposition will be ascertained using the test situations of Project A.

3.1. General Features of the Stress Task

The stress task simulates the role of the operator of a ground missile site that has a defence role. The simulation resembles a last generation system; it is similar in some respects, at the strategic rather than the tactical level, to present day systems. The names of variables employed in the task (such as "height of object," "speed of object") have been chosen for their intelligibility to the subject population, ie., they correspond closely to everyday usage.

Information is received about airborne objects. The operator processes the information to determine the speed, position and type of object. Following a decision rule, a decision is made to destroy the intruder, to ignore it, or to wait for more information. The operator has control of a fixed number of ground-to-air missiles with a "re-load" delay. Given a decision to destroy, a future position of the intruder is computed and a time of fixing specified. Missile(s) are then activated and launched. Section 3.2. details the operator's task for dealing with a single intruder from the receipt of information, noting that the experimental situation usually involves having to deal with more than one object. Stress is induced by increasing the number and frequency of invaders. Section 3.3. states the main hypotheses concerning the influence of strategic dispositon. Section 3.4. presents the main features of the design of the experimental apparatus and the recordings to be used for testing the hypotheses.

3.2. The Operator's Task

The operator receives the following information at time t concerning a flying object (Ω):

1. α_t = radial position in degrees, $0^\circ - 360^\circ$
2. β_t = elevation in degrees, $0^\circ - 90^\circ$

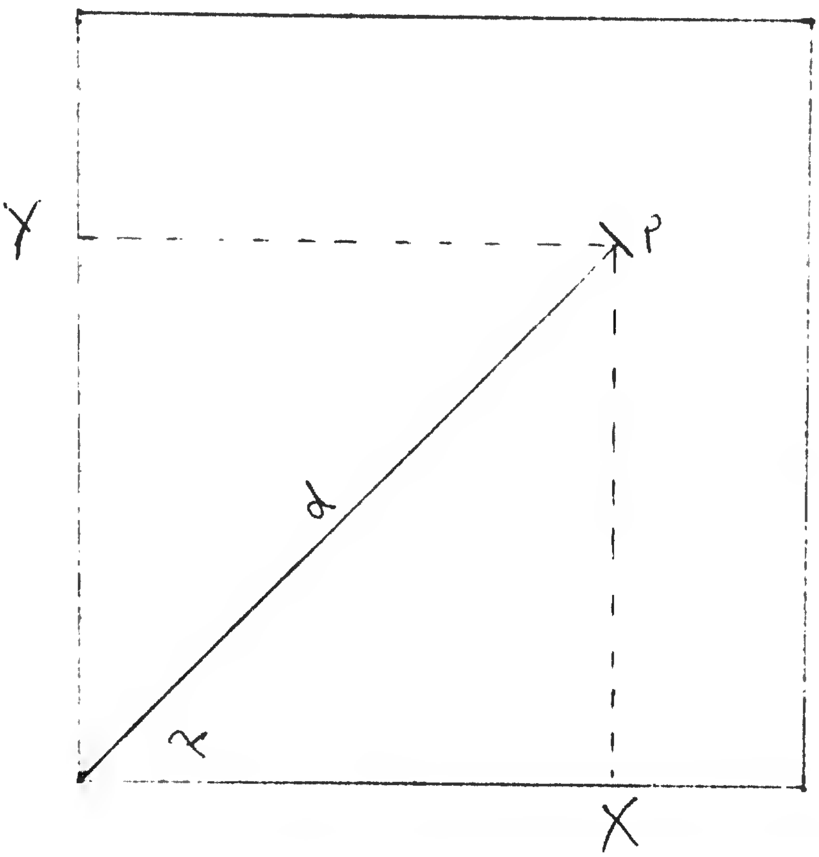


Fig. 1. Translation procedure for values of X and Y.

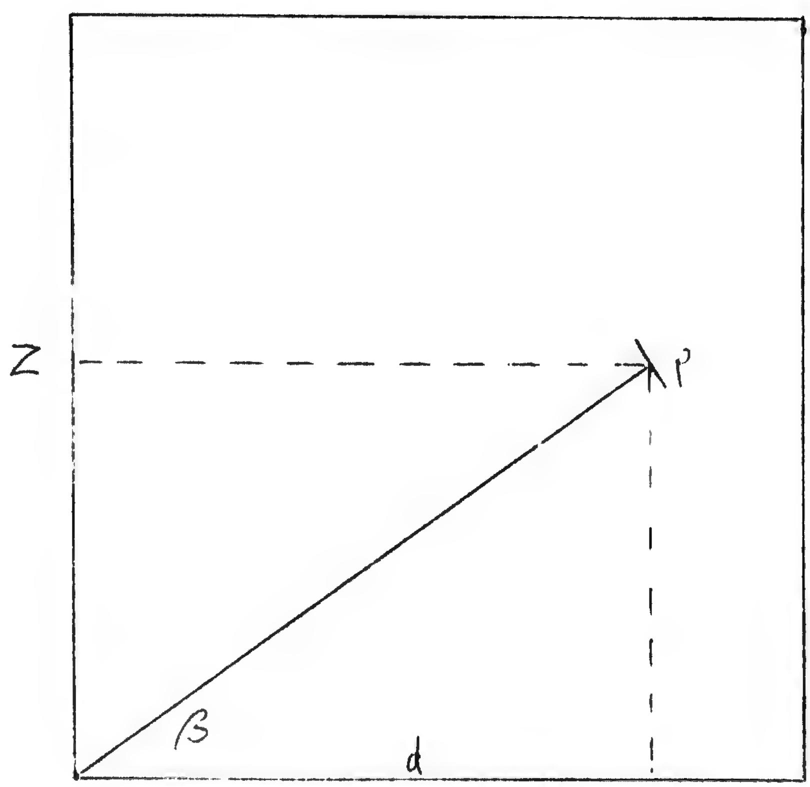
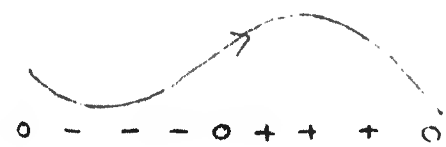


Fig. 2. Translation procedure for value of Z.

1. <u>No change</u>
differences between consecutive values.

2. <u>Slow change</u>
differences between consecutive values.



3. <u>Fast change</u>
differences between consecutive values.

<u>Fig. 3. Course Type Classes</u>.

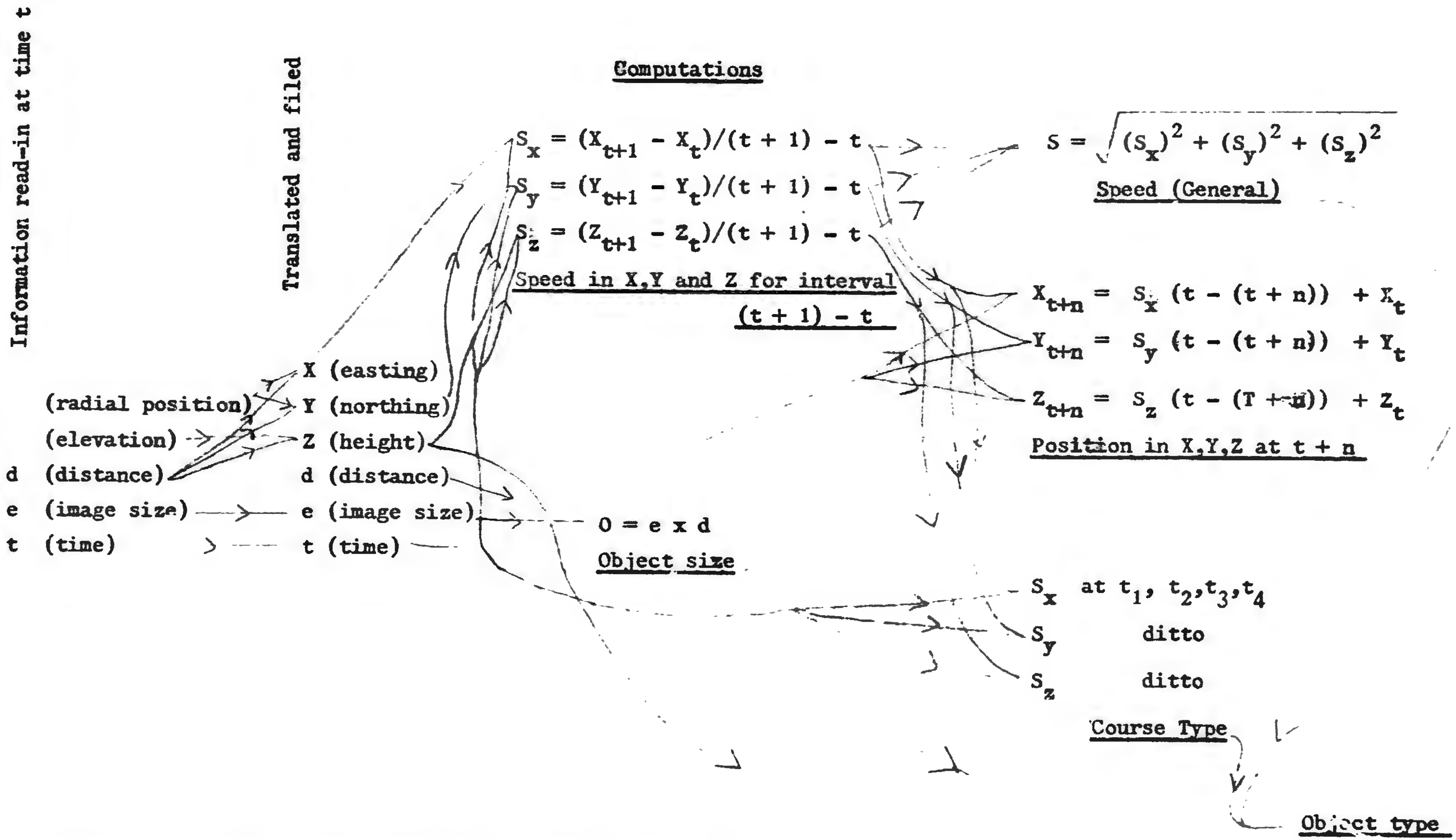


Fig. 4. Main stages in procedure for the case of one object

3. d_t = distance..

4. e_t = perceived size of object.

5. t = time at which observations made.

An initial translation is made to obtain the cartesian co-ordinates, X("easting"), Y("northing") and Z(height). X and Y are found by plotting distance d from the origin for the radial position on a translation board. Values of X and Y are read off as shown in Fig. 1.

Z(height) is found by a similar procedure on a different translation board by plotting distance d along the horizontal axis and fixing a point, P, above d on a line with slope β (elevation) as in Fig. 2. and reading the value of Z from the vertical axis.

Following the initial translation, the values, t,X,Y, Z, d and e are filed for processing.

Further readings for the object, Ω, are obtained at t + 1, t + 2 etc. They are translated and filed similarly.

To indentify the intruder with greatest accuracy values for the following variables are required:

1. Speed S (different types of objects operate in different speed ranges).
2. Course type, C_{XY}, relative to the X and Y axes (objects typically have 1 of 3 course types).
3. Course type, C_Z, relative to the Z axis.
4. Real object size, O (objects have different sizes).
5. Height, Z (objects operate within different height ranges).

To predict the future position of Ω at time, t + n, the speed relative to the X, Y and Z axes is required for some interral ((t + 1) - t), i.e. two sets of translated reading are required.

To determine the values of C_{XY} and C_Z a minimum of four sets of translated readings are required. The course type pattern can then be classified as 1. no change (differences between consecutive values of speed in X,Y,Z are all zero. 2. Slow change (only one difference between consecutive values is zero) and 3. fast change (in four readings, there are two cases where the difference between consecutive values is zero). This is shown graphically in Fig. 3.

Object size, O, is found directly from the product (e x d).

Fig. 4 summarises the main stages in the computations and indicates where the results of earlier computations are required for later computations.

Having identified the object and its speed and position, the operator has to decide what action to take. The basic decision rules are as follows:

1. the aircraft is a Natural Danger (N) or not $(\bar{N})$ (i.e. is an aggressor or not).
2. the aircraft is a Territorial Danger (T) or not $(\bar{T})$ (i.e. has intruded

into friendly territory or not).

a. Given Ω is (NAT) (aggressive intruder) then <u>destroy</u>.

b. Given Ω is $(NA\tilde{T})$ (aggressive non-intruder) then <u>wait/prepare</u>.

c. Given Ω is $(\tilde{N}\tilde{A}\tilde{T})V(\tilde{N}AT)$ <u>IGNORE</u>.

Note that when several objects are aggressive intruders, the operator must weight each Ω for degree of N and T and weight the effectiveness of his defences (numbers of ground-to-air missiles available and reload time and effective range).

When a target has been selected the technique for aiming and shooting is as follows:

Ω(target) must be in the defence position's effective field, specified as ranges $(X_R - X_{\bar{R}})$, $(Y_R - Y_{\bar{R}})$, $(Z_R - Z_{\bar{R}})$ on the XYZ axes.

A collision time $(t + n)$ is chosen for interception, where t is the time of the first observation.

The X,Y and Z co-ordinates for interception are computed as follows:

$$X\ (\text{interception}) = X_t\ (S_x)\ [(t + n) - t]$$

$$Y\ (\text{interception}) = Y_t\ (S_y)\ [(t + n) - t]$$

$$Z\ (\text{interception}) = Z_t\ (S_z)\ [(t + n) - t]$$

For the defence missile to intercept the following equation is solved to give the value of $(t + m)$ the time at which the missile is to be launched:

$$S_R\ \ (t + n) - (t + m) = \sqrt{(X_I - X_{dm})^2 + (Y_I - Y_{dm})^2 + (Z_I - Z_{dm})^2}$$

Subscript "I" denotes interception co-ordinates; subscript "dm" denotes missiles initial co-ordinates.

The values X_I, Y_I, Z_I are set up on the "aim" facility and a defence missile is fired at time $t + m$.

<u>3.3. Hypotheses concerning strategic disposition</u>

The task is designed to show clear distinctions between holist and serialist in the way they carry out the task. The physical set up for the task (detailed in the next Section) consists in a read-in and storage facility; special purpose computational facilities (requiring as a minimum the setting up of input values, as a maximum, the plugging-up of connections between logic and arithmetic units on a "patch-board") and an "aim" facility. Note that <u>all</u> values, those read-in, those input to a facility and those computed by a facility, are probabalistic.

In general a holist is expected to display the following features in his use of the facilities and his decisions made:

He will look for and use (1) redundancies in the information "read-in" and (2) redundancies in computations.

With respect to (1), he will pose hypotheses about the N and T values of objects on the basis of any pattern seen in the behaviour of the objects; in doing so he is open to errors due to over-generalizations. Input series can be specified that encourage or discourage such generalizations.

With respect to (2) he will use the results of partial computations to update the prior probabilities he has assigned to hypotheses at (1) and omit any parts of the computational procedure which have little or no effect on the probabilities he has assigned.

Further, during the computational phase he is likely to work on more than one partial computation at once where the facilities are available for doing so: with respect to a single object, this will appear as his concurrently computing object type as results from computations of object size, speed, position and course type are available and being ready to terminate his computations when the necessary information for deciding what to do is available: for example, the object may be reliably identified before the course type is specified; the object may be classed as a non-aggressor <u>before</u> all details of speed, position and object size are known.

Conversely, a serialist will pose specific hypotheses and reduce his uncertainty about the values of single variables (such as speed, position, object size) before proceeding to pose hypotheses about the type of aircraft and what action to take. He will not be prone to errors due to over generalising but will be less flexible in an overload or stress condition. The serialist, under stress, is expected to fall back to a strictly stage by stage mode of operation, where only high levels of confidence are tolerated for the values of variables computed. He will be swamped by the sheer amount of information processing to be done. The holist, under stress, is expected to fall back more and more to a generalised, global mode of operation, where low levels of confidence are tolerated for the values of variables computed, and decisions are based on consideration of as much of the available information as possible. He will be prone more and more to produce errors that are the result of over-generalization.

In the next Section, the measurement procedures for detecting the holist and serialist modes are detailed as part of the design for the operator's facilities: hypotheses entertained and confidence levels assigned are measured, as far as possible, by recordings of the probabilistic weightings the operator assigns to values set at various stages of his task.

3.4. Details of Operating Facilities and Experimental Recordings

3.4.1. The object identification facility

The facility receives input of values of speed range, course type, object size, height range. Associated with each (as part of the input) is a confidence estimate. The remainder of the input consists in a prior estimations of the probability of the object being of a particular type. Given the input, the facility computes the a posteriori probability of an aircraft type. Note the facility can be used to compute the a posteriori probabilities when the values of some input variables are not yet known; in this case all possible values are assigned equal weights.

3.4.2. The Course Type Facility

This facility accepts a priori estimates of the probability of the course being of a particular type and computes a posteriori probabilities.

3.4.3. Speed in X,Y and Z facility

Given probabilistic estimates of speed at time t and t + 1, in X,Y or Z, this facility computes the probable speed and assigns a weighing to the value.

3.4.4. Object Size Facility

This facility computes the probable object size and assigns a weighting from probabilistic estimates of e(perceived size) and d(distance).

3.4.5. Speed (General) Facility

This facility takes as inputs probabilistic estimates of speed in X,Y,Z and computes a probable speed and assigns a weighting.

3.4.6. Position in X,Y,Z at time t + n

Given probabilistic estimates of speed in X,Y and Z and positon at time t, this facility computes the probable position at time t + n and assigns a weighting.

3.4.7. Computation of Firing time (t + m)

This facility computes the firing time (t + m) and assigns a weighting.

3.4.8. Decision Facility

Given probabilistic estimates of object type, position at t + n, speed, missiles available and missile effectiveness, this facility computes weighted values for N and T over a set of objects.

3.4.9. Aim Facility

This facility accepts X,Y, and Z values for interception and accepts a "fire" signal at t + m.

Together, the decision and aim facilities provide the absolute measures of an operator's effectiveness in terms of accuracy and speed of dealing with objects.

4. Future Plans

4.1. Project A

When the piolt experiments are completed, the main experiments will be run. All subjects will be required to go through the pre-test battery and both testing situation.

4.2. Project B

Pilot experiments are to be run at an early stage with "roughed-up" display facilities for presentation. Results of the pilot study will indicate to what extent (if any) the task may be simplified for the experimental run proper (by, for example, omitting one or more variables from the procedure). As it stands the task is complex and rich enough to make the necessary discriminations reliably; it may well be that a simplified proceuure works; just as well.

5. Difficulties Encountered

No difficulties were encountered during the reporting period.

6. Inventions

No patentable inventions were made during the reporting period.

7. Personnel

There have been no personnel changes during the reporting period.

8. Travel

Dr. Pask presented a paper entitled "A Cybernetic Theory of Cognition and Learning" at the European Meeting on Cybernetics and System Research, Vienna, May 23rd - 27th.

In July, Dr. Pask was participant at a research seminar on "C.A.I." held by the S.S.R.C. of Great Britain, at Edinburgh.

From August 15th - 25th, Dr. Pask visited the U.S.A. he sat on the examining board for Ph.D. students at Georgia Institute of Technology, he was also invited to give a lecture at M.I.T.

Dr. Pask, Mr. Scott and Mr. Kallikourdis participated in a conference on "Self-Referential Systems", held by the Artorga Research Group in London, September 11th - 13th.

Also in September, Dr. Pask presented a paper entitled "The Reactive Environment" at the Computers in Architecture Conference, York University, organised by the B.C.S. and Ariba.

On October 18th, Dr. Pask read a paper to the Moral Sciences Club Cambridge, entitled "A New Theory of Conversations and Learning and Teaching".

9. Publications

The following publications have appeared or have been submitted for publication during the reporting period:

"Anti-Hodmanship: a review of the state and prospects of C.A.I." Journal for Programmed Learning and Educational Technology (September 1672).

"Artificial Intelligence: a preface and a theory" in Machine Intelligence in Design (N. Negroponte, Ed.)

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A series of papers is to be published by the International Journal of Man-Machine Studies. The preface to the series and the first two papers are in press. Titles of papers in series are:-

1. "Learning Strategies and Individual Competence".
2. "Caste: A system for exhibiting learning strategies and regulating uncertainty".
3. "A Theory of Conversations and Individuals".
4. "The Representation of Knowables".
5. "Physical and Psychological Universes".
6. "A Theory of vehicles (M-Inividuals)".
7. "Applications of the Theory of Individuals in Opinion Sampling."

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