Appendices

APPENDIX A: INTUITION OPERATING RULES

The operating rules and transactions are discussed in the context of the "extended probability theory" thesis and the Lumped Modelling Facility STATLAB II. As a matter of convenience, the entailment structure representing this thesis is broken down into three modules that are often presented separately (the three miniature entailment structures). Though this is not a mandatory condition, the description is based on the assumption that one module is studied at once.

Ap. 1. The first rule to be accepted by the student is pragmatic. His *intention* is to learn the topics required in order to *understand* the uppermost topics in the entailment structure (the *head* topic of the previous monograph), and to do so in a manner permitted by the procedural rules indicated below.

Ap. 2. A student can explore any topic by pointing with an electrically connected stylus at the label representing this topic on the entailment structure. For this purpose, the entailment structure serves as a conceptual "map" of topics and their labels, disposed about a territory. The "map" is indexed by *descriptors*, which are displayed explicitly. The descriptors apparent in Fig. 1.3 are *depth* from the head topics taken to name the subject matter field (the "superordinate/subordinate" descriptor of the previous monograph): a descriptor with values *Re* = Real world of experiments; *Ab* = Abstract world of logical or mathematical constructs, and

An = Analogies involved in relations that underlie statistical inference. Finally, there is a descriptor, with values indicated as coloured columns, that discriminates the form of logical expression lying at the root of the topic.

In response to his explore enquiry, the student receives examples of the explored topic presented graphically by slides projected onto a screen (Fig. 1.1) using a random access projector. Each topic is associated with several examples determined by values assumed under different semantic *descriptors*, many of which are not displayed. For instance, the topic "simple random experiment" is exemplified in terms of "games of chance" and in terms of "behavioural experiments". The examples are also indexed by values of the descriptors that appear explicitly in the entailment structure, for example, the real world interpretation (*Re*) and the abstract world interpretation (*Ab*) which in the entailment structure correspond to the left and right hand half planes.

The descriptive examples (Fig. 1.5 is typical) are enriched both pictorially and by multiplicity of context (releaser function and humour). Descriptive examples do not delineate the underlying topic relation which is to be explained if the topic is addressed. But they do systematically discriminate the descriptor values (for example, "plant breeding," as distinct from "games of chance" or "behavioural experiments").

At this stage, the only caveat is that explorations do *not* peter out and that they *do* lead eventually to choice of some focus of attention which is dubbed an aim topic.

Ap. 3. To propose an aim, the student touches a different point on the topic label with his stylus. In response to a proposed aim, he receives a brief test administered by a confidence estimation device (BOSS, or Belief and Opinion Sampling System, Fig. 1.2). Questions cards, indexed by the topic number are inserted into the BOSS card reader, and the apparatus sequences responses and subsequent card insertions and computes a progressive estimate of correct degree of belief signifying that the student can genuinely describe (give veridical descriptor values to) the topic proposed as an aim. If so, the proposed aim is *validated* as a topic the student can appreciate (but not necessarily learn about), and it is instated as the current aim, of which by edict there may be only one. (From the previously considered rules, some one aim must be selected at any rate after an interval of exploration.) The only restriction upon a proposed aim selection is that no topic currently marked as understood is a legitimate candidate.

In return for selecting an aim, the student receives a display, through the illumination of green signal lamps attached to each topic, of the ways in which the aim topic may be derived from other topics; for example, Fig. A.1 shows the display presented if representative topic is cited as aim by the student and if the aim selection is validated by the system.

The display represents the "Entailment Set" (the union of the entailment kernels, as in the previous monograph) of the aim chosen, and consequently, all of the topics that might be learned in getting to know about this particular aim topic. The student is required (by a further rule) to select one or more goal topics, within the "Entailment Set" of his aim topic, as the topic(s) he intends to learn about and work upon. Notably, one possible goal is the aim topic itself.

Ap. 4. Before describing the goal selection procedure, it is necessary to look ahead at the placement of *understanding* markers (plugs with some circuitry inside them, shown in Fig. A.8) and to

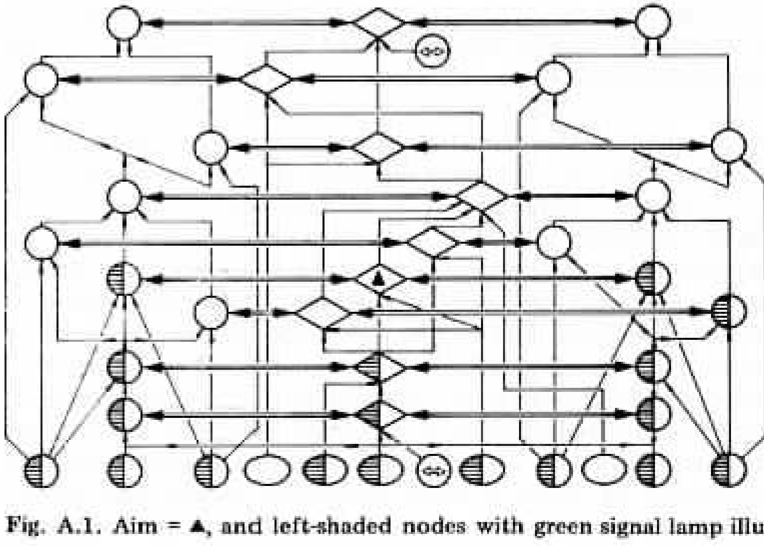

Fig. A.1. Aim = ▲, and left-shaded nodes with green signal lamp illuminated.

recall that any student has agreed to learn and understand all of the head topics. In INTUITION (though *not* in the more elaborate system of CASTE) we suppose that the student either (a) understands all of the lowermost (primitive) topics at the outset and is prepared to start learning from that point onwards, or (b) (an inherently more interesting possibility) that he declares his understanding of the other-than-primitive topics and engages in the "explain of explain" routine. In the latter case the topic is instated if and only if "explain of explain" is completed successfully.

Since case (a) is more easily described and pictured, we concentrate upon it at the moment and return to case (b) later. Now given case (a), all of the nodes of the primitive (lowermost) topics can be marked understood as an initial condition. Understanding is marked by inserting plugs (understanding markers). The result of doing so is to illuminate orange lamps (Fig. A.2) on the nodes of topics entailed by the collection of understood topics. Topics associated with illuminated orange signal lamps are known to the student as possible goals (distinct from legal goals, which will be introduced shortly).

Ap. 5. Return, after this brief digression, to the condition in which the student has selected and validated an aim topic so that topics

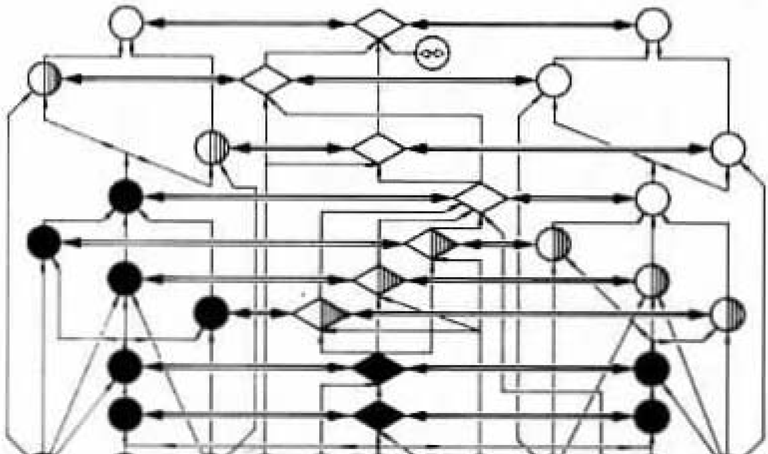

Fig. A.2. = Orange signal lamps (right-shaded nodes) showing possible goals for given distribution of understanding (■ nodes).

in the "Entailment Set" of the chosen aim are associated with an illuminated green signal lamp. If the prerequisites are also marked understood, some topics will thus be associated with both an orange *and* a green illuminated signal lamp. These are legal goals; that is, if the student satisfies the rule requiring him to select some (one or many) goals under his chosen aim topic, then selection of a legal goal or several legal goals will be accepted. The student will be able to access demonstrations and tutorial materials with respect to these topics and to learn about the underlying topic relations. A typical legal goal distribution, at the start of learning, is shown in Fig. A.3(A); a legal goal distribution later in learning (when more understood markers have been inserted) is shown in Fig. A.3(B); a still later legal goal distribution (and under a different choice of aim topic) is shown in Fig. A.3(C). Any attempt to select an illegal goal (any topic that is not marked by an orange and a green signal lamp) is automatically detected; the student receives an auditory signal and the equipment operation is locked until he dismantles the offending configuration either by changing his goal selection or occasionally by changing his aim selection.

In order to choose one or more goals the student must perform the following operations for each goal (Fig. A.4):

(a) Open the door bearing the topic name.

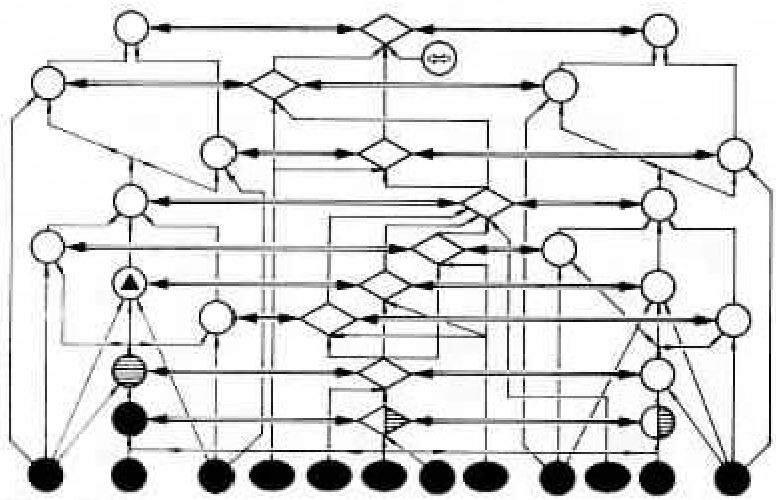

Fig. A.3(A)

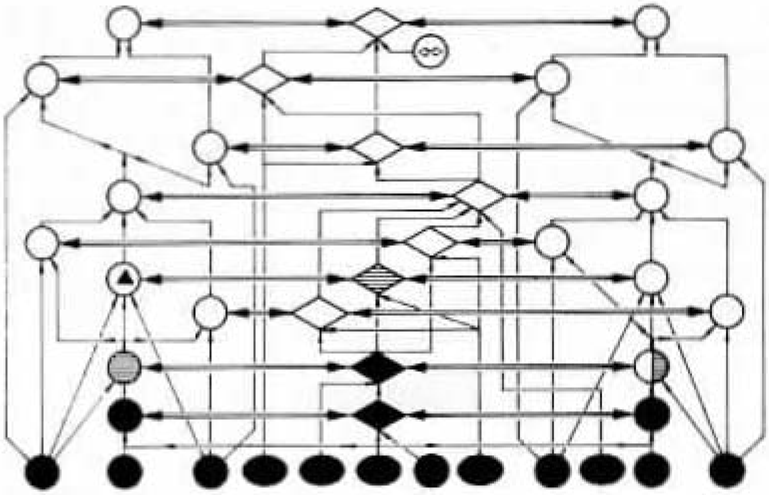

Fig. A.3(B)

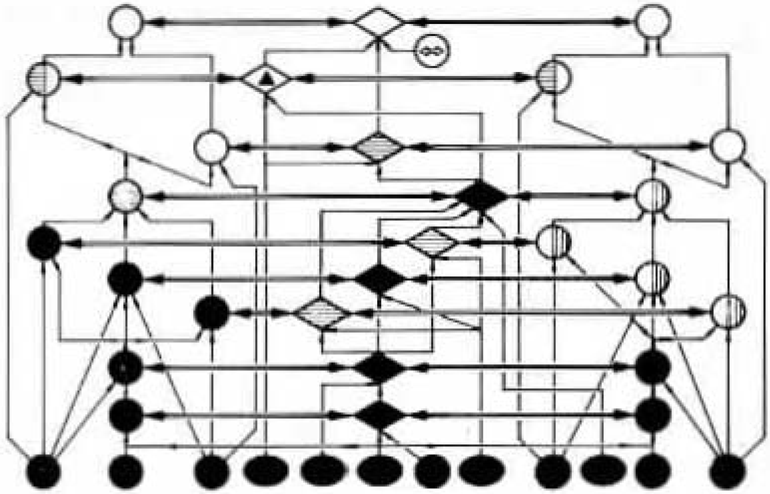

Fig. A.3(C) Aim ▲, Understood ■, fully-shaded nodes = legal goal nodes.

(b) Insert a goal probe (of which six are provided) into a socket thereby uncovered.

(c) Read the index numbers revealed on the reverse side of the topic door.

Regarding operation (c), there are two possibilities depending upon whether the goal topic is or is not representing an analogy relation. If not, the index number is unconditional and the topic position is associated with one orange signal lamp (the possibility so far described). If the topic does represent an analogical relation (for example, any topic in the central part of the display), there is a cluster of orange signal lamps above the topic label and although one of them is illuminated if the topic becomes a possible goal, the particular one depends (1) upon the configuration of understood markers achieved as a result of previous learning, and (2) upon the

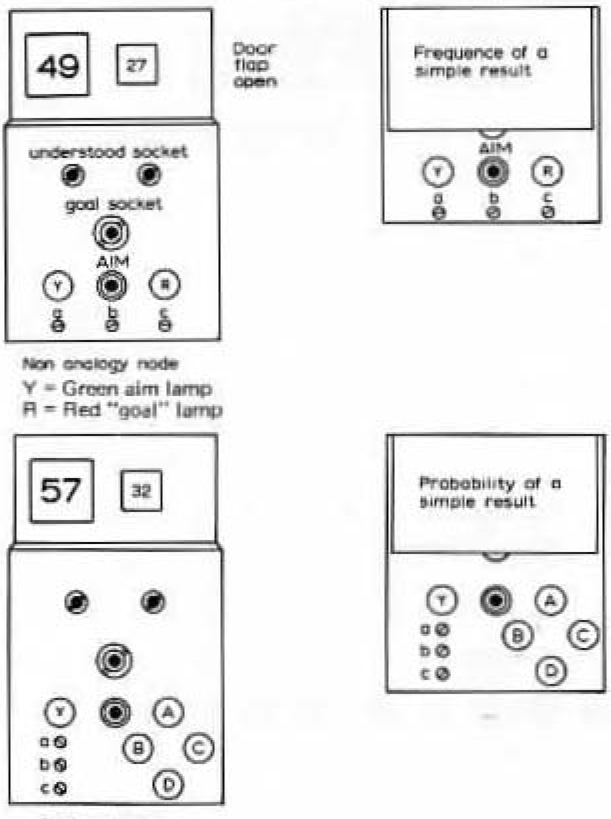

Fig. A.4. Concrete arrangements for nodes of an ordinary topic (above), or an analogical topic (below). a, b, c, are contacts for explore transaction probe. The goal signal lamp (R, above) is replaced by set of signal lamps (A, B, C, D, for 2 term analogical topic).

goal probe insertions currently made by the student.

In the former (unconditional) case, the one index number uniquely specifies demonstration and tutorial data files to which the student is given access. In the latter case, there are as many index numbers as orange signal lamps and the demonstration and tutorial data files are conditional upon the learning process. In Fig. A.4 there are four signal lamps and consequently four contingently accessible types of demonstration.

The conditionality arises because of the curiously complex structure of analogy relations discussed in Chapters 3, 4 and 6. In general, there may be various kinds and numbers of contingencies (for example, 4 to 12 in a thesis on "Heat Engines"), but for "Probability Theory" the contingencies are uniform in kind and readily stated. The configurations which illuminate the different signal lamps are summarised in Fig. A.5. All the analogy relations for this subject matter thesis have the same basic structure with two *terms* (the topics that are analogically related by the central topic), one term representing a "real world" topic and the other term an "abstract world" topic which is its mathematical image.

condition cited in text	left term topic	right term topic	goal lamps illuminated on analogical topic
I	+	+	A
II	+	—	B
III	—	+	C
IV	—	—	D

Fig. A.5. Conditions for learning 2 term analogy, marked as legal goal. + = understood, — = not understood.

Ap. 6. Presupposing a description of the next rule, the orange signal lamp illuminated on the analogical topic determines not only the type of demonstrations which the student can obtain but also the type of non-verbal explanation which the student will be required to produce in order eventually to mark the topic as being understood. Thus, consulting the conditionality table in Fig. A.5, lamp (A) is illuminated if and only if both terms of the analogy relation are understood; lamp (B) if the left hand term but not the right hand term; lamp (C) if the right term but not the left; finally, lamp (D) if neither the right nor the left hand term is already marked as understood but if either one or both of them is marked as a legal goal. If none of these conditions apply, then no lamp is illuminated as the topic is not a possible goal.

In Condition (I), the student (already *understanding* both terms) need only explain the analogy between them and he receives demonstrations only of this analogy relation. In condition (II), the demonstrations exhibit the right hand term by analogy with the left hand term, and an explanation of the analogical relation parallels this transformation. In Condition (III), the reverse applies; the left hand term is demonstrated by analogy with the right hand term and similarly explained. In each case there is a clear sense in which the student already knows one (Condition (II) or Condition (III)) or both of the terms (Condition (I)) before he tackles the analogy between these terms.

Condition (IV) is peculiar and interesting since it represents the case in which the student grasps the analogical relation to begin with and opts to explain the left hand or right hand terms by recourse to this analogy. In order to interpret his explanation, he is forced, before the analogy relation can be understood, to explain it by means of one or both of the terms (consequently placing himself in Condition (I), (II), or (III)). The practical consequence of this preference is that he is forced, before explaining the analogical topic, to mark one or both of the terms as a simultaneously entertained goal topic.

Ap. 7. The tutorial material consists in demonstrations of the topic(s) currently in focus as goals. For a topic T Behavioural Prescriptions (augmented by descriptive text) are derived from the Behaviour Graph BG(T) in the conversational domain, i.e., the Task Structure of *topic* T.

Given the proper index number, the student can access files (Fig. 1.1) containing layover cards (Fig. A.6) accompanied by written text. The layover card (or cards, if there is more than one goal) is placed in front of the fascia of the modelling facility STATLAB II, shown in Fig. 1.1, and outline labelled in Fig. A.6. The card itself, is a Behavioural Prescription, the written text (if any) serves as an accompanying description.

STATLAB II is a Lumped Modelling Facility containing six a priori independent processors (some electrically trivial, though their logical integrity is not).

STATLAB II (Fig. 1.1 and Fig. A.6) is divided into compart-

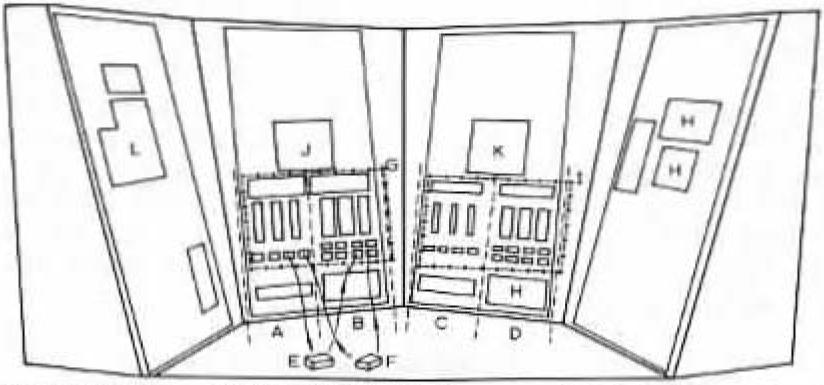

Fig. A.6. Outline of STATLAB II with layover cards. Parts of lumped modelling facility are: A, B, Distinct Universes of real results; C, D, Distinct universes of abstract events; E, F, conditional probability and delay units on Bench; G, Subsets of events; H, measures on event sets and arithmetic operators; J, Matrix of Joint Results; K, Bayesian Inference Summation and Matrix multiplication; L, unique and joint result counters, with marginal totals.

ments in register with the partitioning imposed upon the entailment structure by the descriptors. For example, (Fig. A.6) the lower left hand quadrant is concerned with topics bearing upon a temporally ordered "real world" (*Re*) of deterministic experiments; the lower right hand quadrant with "abstract world" (*Ab*) topics that bear upon set theoretic and atemporal images of deterministic experiments. The upper right quadrant contains topics concerned with frequencies of (temporal) results and their ratios, differences, contingent frequencies, etc. The upper left hand quadrant contains topics that are concerned with measures on abstract sets, conditional measures on product sets, etc. In fact, a finer grained partitioning is possible because the "real world" contains two a-priori-independent universes (in order to develop ideas of contingency, statistical independence, statistical dependence, and so on), and the "abstract world" contains two universes of a-priori-independent abstract images (for reprinting product experiments, conditional probability matrices, and Bayesian Inference).

The non-verbal explanation (or demonstration) of a non-analogical topic involves building a model in one compartment of STATLAB II and any analogical topic is explained by simultaneously executing two models that are analogically related, as required.

Ap. 8. Suppose that one or more layover cards have been removed from the file and placed in position. The student receives a demonstration by obeying the instructions on the card or the accompanying text material, and building a model on STATLAB according to this recipe. When he has done so, the model is executed to achieve some result (for example, to compute the frequencies and expected frequencies of results in an experiment).

For any topic there are several (often five or six) differently slanted demonstrations available in the original file and the student can access as many as he likes, in sequence. The INTUITION equipment keeps a list of the demonstrations of a topic that have been accessed by a student, until the topic in question has been successfully explained.

Ap. 9. When the *student* is satisfied that he comprehends the topic well enough to explain it, he enters the (non-verbal) explanation routine as follows:

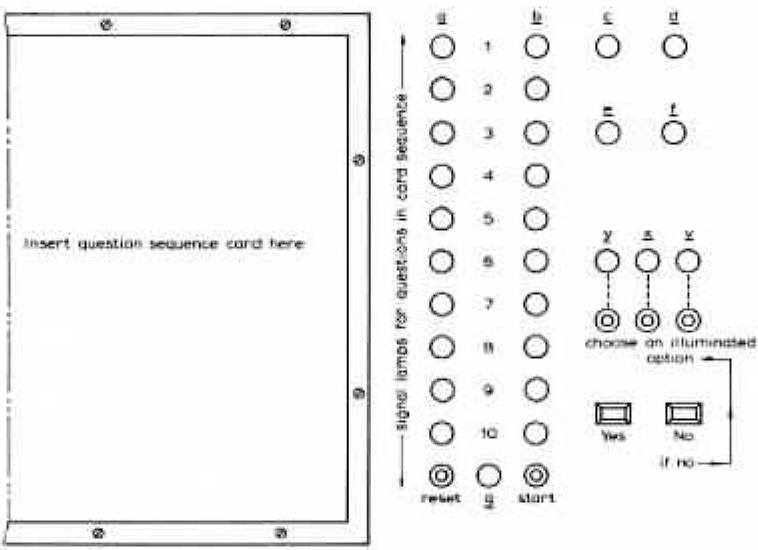

Fig. A.7. Check list questioning device with counter and choice of an option.

(a) All layover cards are returned to the file so that the panels of STATLAB are bare. The equipment is placed in a state that disallows any change of goal or aim, until the explanation is finished. Any attempt to change goal or aim locks the equipment and indicates contravention of this rule.

(b) Explanation is initiated by taking an instruction and check list sheet for the topic concerned and placing it in the check list reader (Fig. 1.1, shown schematically in Fig. A.7). After this point the demonstration file is inaccessible (any attempt to remove a layover card is detected, signalled as illegal, and locks the operation of the equipment).

(c) Card insertion resets a counter in the check list reader, provided that all the requisite conditions such as the existence of an aim and a goal are satisfied. As a result, an illuminated pointer is positioned against the first item in the check list.

(d) Each item in the check list consists in an instruction and a condition to be checked by the student. The instructions guide the student in building a model on STATLAB, which does the same thing as the demonstrations, but which is not identical with any demonstration he has received. This requirement is checked automatically by comparing the model with the set of demonstrations indicated by the demonstration list.

(e) If the student believes that a stage in model building is correct, then he presses the "Yes" button on the check list reader and the pointer moves to the next item. Before pressing the "Yes" button, the student may (and often does) execute the partial model he has built on STATLAB to convince himself that this part does whatever it ought to do.

(f) If he is in difficulties and anxious to start afresh, the student presses the "No" button, which returns the illuminated pointer to an invisible zero position and offers the following options (the lamps and the buttons at the base of the check list reader):

(A) Start a fresh explanation. In this case, the illuminated pointer moves to the first position (the most frequently chosen option).

(B) Obtain further demonstrations. In this case, the student is allowed access to the demonstration file provided the instruction and check list card is removed.

(C) Learn the topic in a different way. Choice of this option resets the entire collection of (internal) electrical register tags established since obtaining a demonstration layover card from the file and allows for change of aim or goal.

(g) Suppose the "No" button is never pressed and that, by pressing the "Yes" button for each item, the student eventually lends his approval to a sequence of partial models (one per item in the check list), and thus has built an entire model for the topic. The last item in the check list always guarantees that this *complete* model *is* executed or tested by the student (partial models may be but *need* not be executed). Pressing the "Yes" button at this point means that the student is satisfied with his model and submits it as a non-verbal explanation of the topic.

(h) Depending upon the experiment, we either accept the student's judgement of workability, invoke the judgement of a supervisor, or use the computer to check that execution of this model correctly satisfies the topic relation. In any case, provisions are made for sensing and tracing (electrically) all configurations of components, links, potentiometer settings, etc. A condensed form of this tracing data is used, in any case, to ensure that the submitted model is not identical with, hence possibly just a copy of, any demonstration on the stored demonstration list.

Ap. 10. Once a non-copied complete model is deemed *correct* (according to one or the other of these criteria) and has been submitted, the student is allowed access to an understood marker and is required to insert it into the entailment structure at the position of the topic which has been non-verbally explained. Simultaneously, the equipment rescinds the temporary (whilst explanation is in progress) edict that neither aim nor goal shall be changed. Insertion of the understood marker, which is based on a sizable plug, is only possible if the goal probe is removed (Fig. A.8). Further, insertion of an understood marker covers and obscures the green and orange signal lamps at the topic position. The student's activities are monitored and mistakes (such as placing the understood marker in a different topic position) lock the operation of the equipment and give rise to a signal.

Ap. 11. Repetition of these operations until the uppermost topics are understood (as agreed by the student in Clause 1) gives rise to

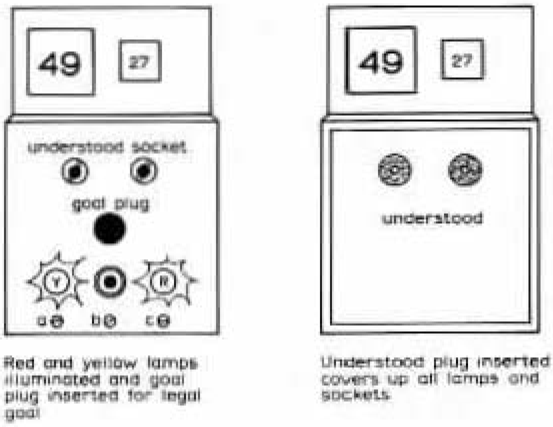

Fig. A.8. Topic node arrangements with, and without, understanding plug inserted.

a series of marker distributions on the entailment structure which is visible to the student as he learns and makes him aware of *how* he *did learn*, as a visual pattern. The distribution of marker patterns and transactions generated in the course of learning is a *learning strategy* and is characteristic of the student.

APPENDIX B: A SIMPLE MODEL FOR AN L-PROCESSOR

The L-Processor is a modular computing machine, the components of which, and their integrity and persistence, depend upon an evolutionary process like Fogel, Owens, and Walsh's simulation (Section 7). The finite state machines are the modular automata which, in such a system, replace indexed storage. They, and their weak interactions, constitute the *PC* operations. But, because the interaction terms are involved in the *PC* specification, a collection of modular automata has a definite L-Processor organisation.

One tangible realisation of a computing medium made up from modular automata is a so called tesselation surface (Fig. B.1): a collection of cells, each containing an automaton, interacting by a neighbour function. (For example, the input to cell ϕ is a function of the previous states assumed by the automata right, left, up, and

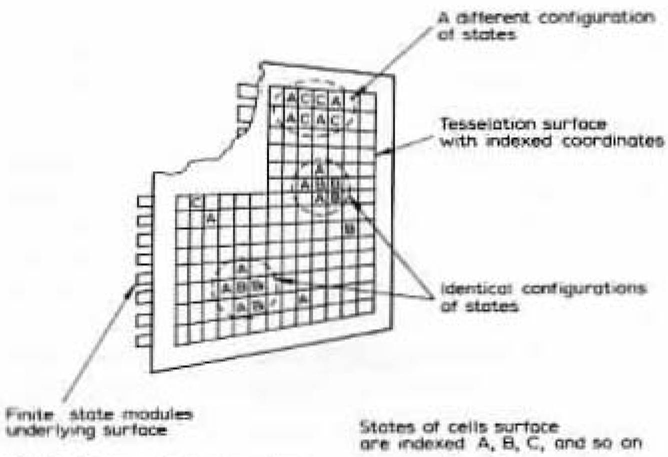

Fig. B.1. Tesselation surface.

down, adjacent to ϕ.) * Arrangements of this kind are used to represent reproducing automata. The entity being "reproduced" is a *configuration* of states of modular automata, irrespective of where upon the surface it is located. The surface, in other words, is a *computing medium* (a taciturn system) inhabited by procedures (here configurations) which survive or decay. Under the immediate interpretation, *understanding* and memories figure as *configurations*, the *DB/PB* operations as the dynamics of strong interaction between *configurations*, and these strong interactions, in turn, as the L transactions of a language oriented system.

Finally, the compilation Inter of a Program Prog (to realise Proc = ⟨Prog, Inter⟩) is that activity in the states of certain modular automata which induces a state of a configuration (Prog) and does so for each state of Prog. Hence Inter belongs to the class of *PC* operations, any Proc has a *PC* component in it as required by the overall theory.

* Probably the simplest tesselation system is Conway's (1971) "Life" Simulation, but it is marginally adequate for the present purpose. Other more elaborate tesselation systems are described in Burkes (1970). To exemplify the notion, several systems have been simulated with one additional, mathematically irritating but *essential* property; namely, that a modular automaton is never sessile, i.e., the automata act as oscillators damped by weak *interaction* with their neighbours.

In such an arrangement, it is possible to vary the composition of the automata (they may be uniform or varied), the neighbour function (it may be homogeneous at all points on the surface, or not), and less plausibly, when it comes to physical interpretation, the dimensionality of the tesselation surface. Any or all of these parameters constitute "patterns of L-Processor organisation", as the phrase was used in the paragraph before last. Moreover, at least one of these parameters is varied if the modular automata are produced and refurbished by an evolutionary style process (Fig. B.2).

Provided certain limiting conditions are respected, these variations do not influence what may be computed by *configurations* on the tesselation surface (for example, reproductive Turing automata can be represented in any such system). But the parametric variations *do* profoundly influence how the computation takes place, and it is surely possible to set the parameters (in many ways, in fact) to capture each competence profile. Moreover, the parameter setting may be (and in Fig. B.2 it will be) determined adaptively, as required if this picture of things is to match the observations of other researchers or of our own group.

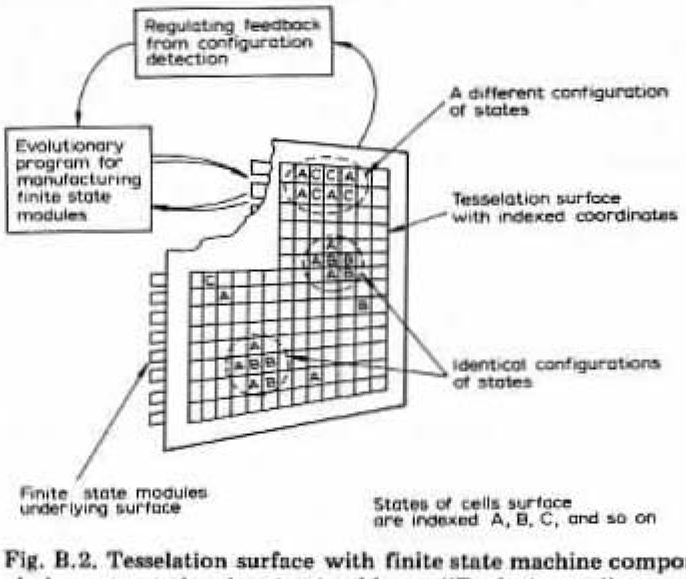

Fig. B.2. Tesselation surface with finite state machine components (the modules) constructed and maintained by an "Evolutionary" program.

That is, depending upon the characteristics of the *computing medium* (or candidate as an L-Processor), a *DB* operator (if it exists) will be a *GDB* or an *LDB*; similarly, a *PB* operator (if it exists) will be a *GPB* or an *LPB*. This global or local propensity is the least readily modified; the effectiveness of *DB* and the effectiveness of *PB* operations depend by hypothesis upon the steady state densities of *DB* and *PB* amongst the population of programs under execution in this medium.

We do not hold that L-Processors (in particular brains) actually *are* organisations on a tesselation surface; the tesselation surface was introduced as a familiar example. But any set of interacting modular automata have communication and control connections equivalent to neighbour functions and the like, and we do maintain that L-Processors are just such systems. †

† It is worth noting that a number of telling parallels exist between processors of this kind and biological or physiological systems. For example, Goodwin's (1963) discussion of cellular metabolism makes a clear distinction between weak interactions through pools of metabolites (reaction products and precursors) and the strong interactions implicating DNA, RNA, the Ribosomes, and Enzyme synthetic processes, which may be regarded as *DB/PB* replicable procedures executed in the milieu of the cell. Pringle (1951) and Beurle (1954, 1959) entertained similar notions with specific interpretations in Brain Dynamics; so, with some variations, did Hebb (1949). Since that era, a host of comparable formulations has been devised in diverse fields; for example, neurophysiology, molecular biology, biochemistry, genetics, ethology and ecology. One fascinating example which has recently aroused lively interest (see, for instance, the proceedings of the December 1974, Faraday Society Symposium, No. 9) is a system of spontaneous chemical oscillations in a dish of Belousov reagent. (Bromate ion in sulphuric acid solution with malonic acid and reducible manganese or cerium ions).

It is quite important to recognise that these conditions are the norm (for otherwise the argument seems curiously outlandish) and that the more familiar cases of serial execution are specially contrived and seldom encountered in nature. That is, most natural systems are *not* subject to the limitation, "stop execution whilst rewriting a program, and stop rewriting whilst execution is in progress," which we used in the first monograph to *delineate* the class of serial modelling facilities to which this very special caveat properly applies (the "t clock" and the "τ clock" convention). See also Pask (1961, reprinted 1968, 1972) and Pask (1975a) as well as Ben Eli (Brunel University thesis, 1976).

APPENDIX C: DETAILS OF COMPROMISE PROCEDURES FOR "LEARNING TO LEARN" EXPERIMENTS

The following compromise procedures stem from an application of entailment structure techniques devised and successfully pilot studied by Dr. R. Glanville and his colleagues in the context of an architecture school.

Session A

After students have studied the texts, lists of topic names, to which others may be added by individuals, are handed out, and each student is asked to rate the topics as follows: + if he thinks he can explain the topic, ? if he is doubtful, — if he cannot, and * if the topic is irrelevant (some seemingly irrelevant topic names are given in the list, together with some "spare" locations to be filled by additional topic names). The students are asked to show by directed arcs how they conceive the topic to be "connected". Typical results are shown in Fig. C.1 and Fig. C.2. Students are next given a sheet on which the experimenter has encircled the topic names which each *individual* student thinks he is able to explain (hence, each student has a "personalised" sheet), and the class is asked to construct a similar connection graph for these topics only (Fig. C.3 and Fig. C.4). Essay questions, as well as interviews, are used to check that students who *say* they can explain a topic *can*, in fact, do so.

Interim A, B

Between Session A and Session B, the connection graphs are computer processed to give a pruned version in which the analogical convention is inserted.

Session B

At the start of the training session, the computer processed, individual connection graphs are returned as "feedback" and are used in the "learning to learn" exercises. Further and more sophisticated structures are built up as the various principles are introduced. Amongst other things, the distinction between formal and analogical derivations is established.

A = Law of 3
B = Law of 7
C = Collig. 1
D = Collig. 2
E = Activation
F = Active force
G = Passive force
H = Neutral force
I = Animus
J = Anima
K = Tao
L = Yan
M = Ying
N = Hsing
O = Ming
P = Interpen of opps
Q = Neg of neg
R = Trans quant to qual
S = Satori - 48
T = Satori - 24
U = Satori - 12
V = Satori - 6
W = Satori - 3
Y = Predestination

a = recepts
b = percepts
c = concepts
d = self consciousness
e = cosmic consciousness
f = simple consciousness
g = self
h = God
i = taboo of tapoos
j = unit of evolution
k = creatura
l = intelligent universe
m = intuition
n = cybernetic system
o = unit of mind
p = unit of information
q = diff that makes a diff
r = difference
s = sap
t = programming
u = territory
v = any concepts

	Student 1	Student 2	
Session A	1	2	All topics
	3	4	+ only topics
Session C	5	6	All topics
	7	8	+ only topics

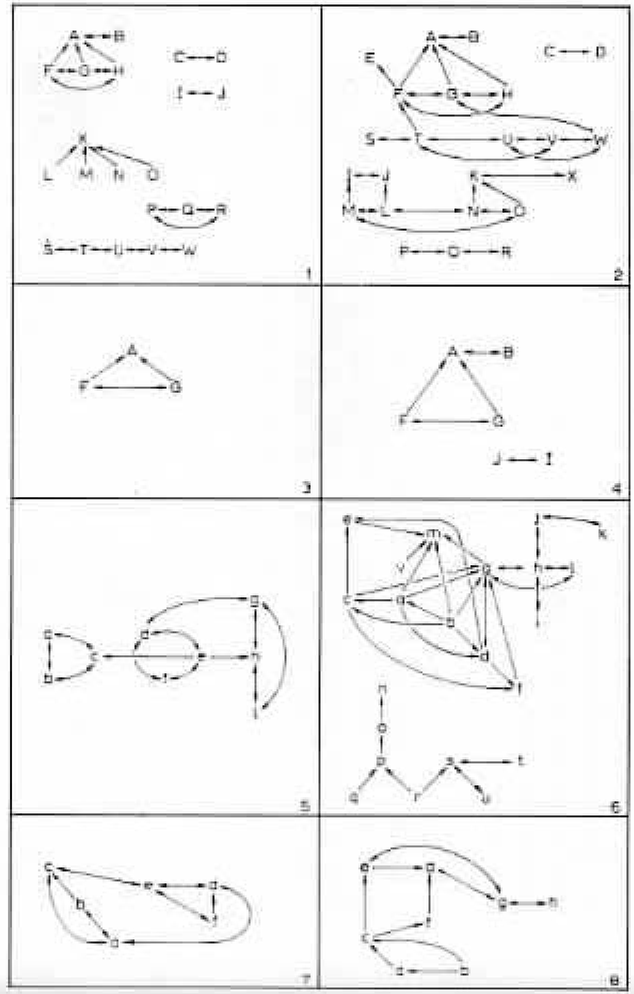

Fig. C1—8.

Interim B, C

Graphs obtained from the students during the training session B are individually processed and returned as "feedback" before the students start to learn the Session C texts.

Session C

After studying the texts, students are subjected to a repetition of the procedures described for Session A. At this stage, they have a more sophisticated repertoire of representational techniques and have been exposed to the "learning to learn" training of Session B. Clearly, the representation skill and "learning to learn" are interrelated, but not identical. Typical connection graphs are shown in Fig. C.5 and Fig. C.6 ("all" topics) and Fig. C.7 and Fig. C.8 (+ marked topics).

Revisiting

These graphs are personally processed and returned as "feedback" somewhat later. If possible, we use "feedback" delivery to ask for repertory grid descriptors elicited over terms of the analogies, and students who cooperate in this matter assign values to their own descriptors.

Discussion

Apart from comparing factual and explanatory responses, it is possible to obtain indices of complexity and coherence over the individual connection graphs. Hence, we are in a position to observe "learning to learn" (students for whom increased understanding after the training session is accompanied by an ability to represent the subject matter), different types of representation, and when they occur, the defects in learning such as "Globetrotting". The latter condition, for example, is detected by noting no difference between the "can explain" connectivity and the "all topic connectivity"; at a more detailed level, by specific "false analogy" patterns. Such deficiencies are generally reduced by training in the "learning to learn" session, and for some of the students virtually eliminated.

References

Abbot, E.A. (1884). *Flatland.* Oxford: Blackwell.

Ackoff, R. (1973). "Science in the systems age," *Operations Research*, May/June, 661—671.

Ackoff, R.L., and Emery, F.E. (1972). *On Purposeful Systems.* London: Tavistock Publications.

Aish, R. (1974). "An Analytical Approach to the Design of a Man-Machine Interface." Ph.D. thesis, Dept. of Electrical Engineering Science, University of Essex.

Allen, L.E. (1974). "Understanding of structured problem solutions," *Instructional Science*, Vol. 3, No. 4, 327—350.

Andreka, H.; Gergely, T.; Nemeti, I. (1973a). "Toward a General Theory of Logics. Part 1. On universal Algebraical Construction of Logics." Hungarian Academy of Sciences, Central Research Institute for Physics, Budapest.

Andreka, H.; Gergely, T.; Nemeti, I. (1973b). "On the role of general system theory in the cognitive process," symposium on cognitive processes, 2nd Conference of the Austrian Society for Cybernetic Studies, Vienna, Austria, pp. 137—150 in *Progress in Cybernetics and System Research.* Vol. II, Eds. R. Trappl and F. de P. Hanika. Washington: Halstead Press, 1975.

Ashby, W.R. (1964). "Measuring the Internal Informational Exchange in a System." Paper presented at 4th Intl. Cong. Cybernetics, Namur, 1961. *Cybernetica.* Vol. VIII, No. 1, 1965, 5—22.

Atkin, R.H. (1972—74). Research Reports 1—4, Urban Structure Research Project, Dept. of Mathematics, University of Essex.

Atkin, R.H. (1973). *Mathematical Structures in Human Affairs.* London: Allen and Unwin.

Atkinson, R.C., and Shiffrin, R.M. (1965). "Mathematical models for memory and learning," *Technical Report 79.* Inst. for Math. Studies in the Social Sciences, Stanford University, Calif.

Atkinson, R.C., and Shiffrin, R.M. (1967). "Human memory: a proposed system and its control processes," *Technical Report 110.* Inst. for Math. Studies in the Social Sciences, Stanford Univ., Calif.

Bachelard, G. (1970). *La Formation de l'Esprit Scientifique*. Paris: J. Vrin.
Baldwin, A.L. (1966). "Information Structures," in *Learning about Learning*, Ed. J. Bruner. U.S. Dept. of Health, Education and Welfare.
Bannister, D., and Mair, J. (1968). *The Evaluation of Personal Constructs*. New York: Academic Press.
Barnett, H.G. (1953). *Innovation. The Basis for Cultural Change*. New York: McGraw-Hill.
Bartlett, F.C. (1932). *Remembering*. Cambridge: Cambridge University Press.
Bateson, G. (1952). *Steps Towards an Ecology of Mind*. London: Intertext Books.
Bateson, G. (1958). *Naven*. 2nd Ed. Stanford, Calif.: Stanford University Press.
Bateson, M.C. (1972). *Our Own Metaphor*. New York: A. Knopf.
Beer, S. (1966). *Decision and Control*. New York: Wiley.
Beishuizen, J.J. (1974). "Interaction between teaching-strategy and learning habits in a program on syllogistic learning." Pre-print for 1975 IFIP Congress on Computers and Education.
Bettelheim, B. (1967). *The Empty Fortress*. Don Mills, Ont.: Collier MacMillan.
Beurle, R.L. (1954). "Activity in a block of cells capable of regenerating impulses." RRE Memoranda, 1042 and 1043.
Beurle, R.L. (1959). "Storage and manipulation of information in the brain," *J. Inst. Elec. Engrs.* 5 (new series).
Bieri, J., Atkins, A.L., Briar, S., and Tripodi, T. (1966). *Clinical and Social Judgement*. New York: Wiley.
Bradley, F.H. (1914). *Essays on Truth and Reality*. Oxford: Oxford University Press.
Bree, D.S. (1974). "Queries and theories," *Instructional Science*, Vol. 3, No. 3, 205—230.
Brillouin, L. (1964). *Scientific Uncertainty and Information*. 1st Ed., 1953. London: Academic Press.
Brillouin, L. (1965). *Science and Information Theory*. London: Academic Press.
Broadbent, D.E. (1957). *Perception and Communication*. Oxford: Pergamon Press.
Broadbent, D.E. (1963). "Flow of information within the organism," *Jnl. of Vbl. Lng. and Vbl. Beh.* 4, 34—39.
Broadbent, D.E. (1971). *Decision and Stress*. London: Academic Press.
Bruner, J.S. (1966). "The will to learn," *Commentary*. Harvard, 41—47.
Bruner, J., and Clinchy, B. (1966). "Towards a Disciplined Intuition," in *Learning about Learning*, Ed. J. Bruner, pp. 71—84. U.S. Department of Health, Education and Welfare.
Bruner, J., Goodenow, J., and Austin, G. (1956). *A Study of Thinking*. New York: Wiley.
Bryan, W.L., and Harter, N. (1899). "Studies on the telegraphic language. The acquisition of a hierarchy of habits," *The Psychological Review*, Vol. VI, No. 4, 345—375.
Bunderson, C.V. (1967). "Transfer of mental abilities at different stages of practice in the solution of concept problems," *E.T.S.R. Bulletin* 67. 20, NONR Report 1855815.

Bunderson, C.V., and Merrill, D.M. (1973). *TICCIT Project Reports* (various). Brigham Young University, Utah.

Burkes, A.W., ed. and contrib. (1970). *Essays on Cellular Automata*. Urbana: University of Illinois Press.

Cassirer, E. (1946). *Language and Myth*. New York: Dover.

Chang, C.L., and Lee, Y.L. (1973). *Symbolic Logic and Mechanical Theorem Proving*. New York and London: Academic Press.

Cin Dal, M. (1973). "Fault Tolerance and Stability of Fuzzy Automata," *Lecture Notes on Computer Science*. Vol. 11, 36—44. Berlin: Springer Verlag.

Cin Dal, M. (1974). "Modifiable Automata and Learning." Proc. 2nd European Cybernetics and Systems Research Conference, Vienna.

Codd, E.F. (1968). *Cellular Automata*. New York: Academic Press.

Codd, E.F. (1970). "A relational model of data for large shared data banks," *ACM*. 13(b), 337.

Cohen, J. (1964). *Behaviour in Uncertainty*. London: George Allen & Unwin.

Cohen, J. (1972). "A confirmation of the inertial effect in sequential choice and decision," *Br. J. Psychol.* 63, 1, 41—46.

Conrad, C. (1974). "Context effects in sentence comprehension, A study of the subjective lexicon," *Memory and Cognition*. Vol. 2, No. 1, 130—136.

Conrad, R. (1954). "Missed signals in a sensorimotor skill," *J. Exp. Psych.* 48, 1—9.

Conway, J.H. (1970). "Game of Life," *Scientific American*, October. (see also M. Gardner, *Scientific American*, February 1971).

Craik, K. (1966), in Ed. Sherwood, *The Nature of Psychology*. Cambridge: Cambridge University Press.

Daniel, J.S. (1974). "Knowables, Conversations and Learning: A Summary of Recent Work at System Research Inc." Tele-University, Quebec, Canada.

Daniel, J.S. (1975). "Conversations, individuals and knowables: toward a theory of learning," *Engineering Education*. Feb., 415—420.

De Fanti, T. (1975). "Toward Loopless Interactive Programming," *Proceedings of the Conference on Computer Graphics, Pattern Recognition and Data Structure*. IEEE Catalogue Number: 75CH0981-1C, May 14—16.

De Fanti, T., Sandin, D.J., and Nelson, T.H. (1975). "Computer graphics as a way of life," in *Computer and Graphics*. Vol. 1, 9—15.

Dirkzwager, A. (1974). "Computer Based Testing with Automatic Scoring Based on Subjective Probabilities." Pre-print for the 1975 IFIP Congress on Computers in Education.

Edwards, W. (1968). "Conservatism in Human Information Processing," in *Formal Representation of Human Judgment*, Ed. B. Kleinmuntz. New York: Wiley.

Elshout, T., and Elshout, M. (1960). "The Programmed Instruction of Problem Solving," in *Programmed Learning Research*, Eds. F. Bresson and D. de Montmollin. Paris: Dunod.

Entwistle, N.J. (1975). "How Students Learn: Information Processing and Intellectual Development," *Higher Ed. Bulletin*. University of Lancaster.

Ernst, G.W., and Newell, A. (1969). *GPS: A Case Study in Generality and Problem Solving*. New York and London: Academic Press.

Evans, C.R., Longden, M., Newman, E.A., and Pay, B.E. (1967). "Auditory 'Stabilised Images'; Fragmentation and Distortion of Words with Repeated Presentation Row," *Report Auto 30*. Autonomics Division, National Physical Laboratory, Teddington.

Feigenbaum, E.A. (1959). "An Information Processing Theory of Verbal Learning," *Report P 1817*. Rand Corporation, Santa Monica.

Feigenbaum, E.A. (1964). "Elements of an Information Processing Theory of Memory," *Am. Psychol. Assoc. Ann. Meeting*.

Feigenbaum, E.A., and Simon, H.A. (1962). "Generalisation of an Elementary Perceiving and Memorising Machine," *Information Processing* (IFIP Proceedings). Amsterdam: North-Holland, 401—406.

Festinger, L. (1957). *A Theory of Cognitine Dissonance*. New York: Ran Peterson.

Fischer, R. (1969). "The Perception-Hallucination Continuum (A Re-examination), Diseases of the Nervous System," reprinted in *Artoraga*, Nos. 125 and 126.

Fischer, R. (1974). "A Cartography of the Ecstatic and Meditative States," *Cybernetics of Cybernetics*. Biological Computer Laboratory, University of Illinois, Urbana, Illinois.

Flavell, J.H. (1963). *The Developmental Psychology of Jean Piaget*. Princeton, New Jersey: Van Nostrand.

Fogel, L.J.; Owens, A.J., and Walsh, M.J. (1966). *Artificial Intelligence Through Simulated Evolution*. New York: Wiley.

Fromm, E. (1951). *The Forgotten Language*. New York: Rinehart.

Gaines, B.R. (1969). "Adaptively controlled instruction for a tracking skill," *Programmed Learning Research*. Proceedings of the NATO Symposium on Major Trends in Programmed Learning Research, Nice, 1968. Paris: Dunod.

Galton, F. (1883). *Inquiries into Human Faculty*. London and New York: MacMillan.

Gergen, L.J., and Morse, S.J. (1967). "Self Consistency Measurement and Validation," *Proc. 75th Annual Convention of the APA*. 207—208.

Glanville, R. (1975). "A Cybernetic Development of Epistemology and Observation, Applied to Objects in Space and Time (As Seen in Architecture)." Ph.D. thesis, Brunel University, Dept. of Cybernetics.

Goguen, J. (1968). "The logic of inexact concepts," *Synthese*. 19, 325—373.

Goodstein, R.L. (1962). *Fundamental Concepts of Mathematics*. London: Pergamon.

Goodwin, B.C. (1963). *Temporal Organisation of Cells*. London and New York: Academic Press.

Gordon, W.J.J. (1961). *Synectics*. London: Collier MacMillan.

Gordon, W.J.J. (1966). *The Metaphorical Way of Learning and Knowing*. Boston: Porpoise Books.

Guildford, J.P. (1956). "The structure of intellect." *Psych. Bull.*, 53, 267—293.

Hankins, G. (1974). "Motivation and individual learning styles," *Engineering Education*. March, 405—411.
Harlow, H.F. (1959). "Learning Set and Error Factor Theory," *Psychology: The Study of a Science*. Vol. 2, Ed. S. Koch. New York: McGraw-Hill.
Hartman, R. (1969). *The Structure of Value*. Carbondale, Ill.: University of Southern Illinois Press.
Hawkins, D. (1969). "The Nature of Purpose," in *Purposive Systems*, Eds. H. von Foerster, et al. New York: Spartan and London: MacMillan.
Hayes, J.B. (1965). "Problem topology and the solution process," *Jnl. Vbl. Learn. & Verb. Behav.* 4, 371—379.
Hebb, D.O. (1949). *The Organisation of Behaviour*. London: Wiley.
Helson, H. (1964). *Adaptation Level Theory*. New York: Harper and Row.
Hesse, M. (1963). *Models and Analogies in Science*. London and New York: Sheed and Ward.

Inhelder, B. (1921—1968). For English reference list, see Flavell.

James, W. (1890). *Principles of Psychology*. New York: Holt.

Kelley, C.R. (1966). "Design Application of Adaptive Simulators," MIT/NASA Working Conference on Manual Control, Cambridge, Mass.
Kelly, G.A. (1955). *The Psychology of Personal Constructs*. Vols. I and II. New York: Norton.
Klix, S. (1973). *Information und Verhalpen. Kybernetische Aspekte der Organischen Informationsverarbeitung. Einfuhrung in Naturwissenschaftliche Grundlagen der Allgemeinen Psychologie*. Berlin: VEB Deutsche Verlag der Wissenschaften.
Koestler, A. (1964). *The Act of Creation*. London: Hutchinson.
Koestler, A. (1967). *The Ghost in the Machine*. London: Hutchinson.

Lakatos, I. (1968). "Criticism and the Methodology of Scientific Research Programmes." *Proceedings of the Aristotelian Society*. 69, 149—186.
Lakatos, I. (1973). "History of the Science and its Rational Reconstruction," in *Boston Studies in the Philosophy of Science* VIII. Dordrecht: Reidel. (See also in same volume, criticisms of "Research Programmes" by Kuhn, Feigel, Hall, Kortge and Lakatos 19).
Landa, L.V. (1971). *The Algorithmicisation of Instruction*. Trans. by V. Bennet and Ed. by F. Kopstein. Englewood Cliffs, N.J.: Educational Technology Publishers.
Lewin, K. (1936). *Principles of Topological Psychology*. Trans. by F. Heider and G.H. Heider. New York: McGraw-Hill.
Libassi, P.T. (1974). "Where the past is present," *The Sciences*. Vol. 14, No. 8, 17—24.
Loefgren, L. (1972). "Relative Explanations of Systems," in *Trends in General System Theory*, Ed. G. Klir. New York: Wiley.
Luria, G.R. (1961). *The Role of Speech in the Regulation of Normal and Abnormal Behaviour*. London: Pergamon Press.
Lynch, K. (1960). *The Image of a City*. Cambridge, Mass.: M.I.T. Press.

Mackworth, J.F. (1959). "Paced memorizing in a continuous task," *Brit. J. Exp. Psych.* 58, 206—211.

March, L., and Steadman, P. (1971). *The Geometry of the Environment.* London: RIBA Publications.

Maslow, A.H. (1954). *Motivation and Personality.* New York: Harper and Row.

McLuhan, M. (1970). *Understanding the Media: The Extension of Man.* New York and London: McGraw-Hill.

Mead, M. (1942). *Growing Up in New Guinea.* Harmondsworth: Penguin Books (first published in 1930).

Mead, M. (1943). *Coming of Age in Samoa.* Harmondsworth: Penguin Books (first published in 1928).

Mead, M. (1957). *Proceedings of Macey Foundation Symposia.* Ed. H. Von Foerster. Princeton: Princeton University Press, 1946 to 1956.

Mendelsohn, G.A., and Griswold, B.R. (1966). "Assessed creative potential: vocabulary level and sex as predictors of the use of cues in problem solving," *Jnl. Personality and Social Psychology* 4.4, 423—431.

Meredith, G.P. (1966). *Instruments of Communication.* London: Pergamon Press.

Merrill, D.M., and Gibbons, A.S. (1974). "Behavioural Hierarchies for Sequencing Content in Instruction," *Proceedings, Fifth Annual Interdisciplinary Conference on Structural Learning.* No. 131-356X, Office of Naval Research.

Michon, J.A. (1966). "The internal representation of associative data networks," *Psychology.* 23, 7, 428—457.

Miller, G.A. (1956). "The magical number seven, plus or minus two; some limits on our capacity for processing information," *Psych. Review.* 63, 81—97.

Miller, J.C. (1965). "Living Systems: Structure and Process" and "Living Systems: Cross Level Hypotheses" in *Behavioural Science* Vol. 10, No. 4, October 1965, 337—411.

Miller, J.G. (1976). *Living Systems.* New York: McGraw-Hill.

Minskaya, G.I. (1954). "Transition from Visual Active to Reasoning Thought in Childhood," Ph.D. thesis, Moscow University.

Minsky, M. (1974). "A Framework for Representing Knowledge," Artificial Intelligence Memo. No. 306, Massachusetts Institute of Technology, AI Laboratory.

Muller, R.E. (1968). *The Science of Art.* London: Rapp and Whiting.

Negroponte, N. (1970). *The Architecture Machine.* Cambridge, Mass.: M.I.T. Press.

Negroponte, N. (1975). "Idiosyncratic Systems," MIT Report Architecture Machine Group.

Nelson, T. (1974). *Computer Lib.* Chicago: Hugos Books.

Newell, A., and Simon, H.A. (1972) *Human Problem Solving.* New York: Prentice Hall.

Osgood, C.E. (1962). "Studies on the generality of affective meaning systems," *Jnl. Am. Psychol.* 17, 1—10.

Osgood, C.E., Gucci, G.J., and Tannenbaum, P.H. (1957). *The Measurement of Meaning.* Urbana: University of Illinois Press.

Papert, S. (1970). "Teaching Children Thinking," *Proc. IFIP Conf. on Computer Education, Amsterdam* (Reprinted in *Mathematics Thinking, Bull. of Assoc. of Teachers of Mathematics.* No. 58, 1972).

Pask, G. (1961). *An Approach to Cybernetics.* London: Hutchinson (Radius Books, Hutchinson 1968, 1972).

Pask, G. (1970). "The Meaning of Cybernetics in the Behavioural Sciences," in *Progress of Cybernetics,* Vol. 1, Ed. J. Rose. London: Gordon and Breach. Reprinted in *Cybernetica* 3 and 4 (1970) 140—159 and 240—250; in *Artoraga* (1971) 156—180; in *Cybernetics of Cybernetics* (1974), Biological Computer Laboratory, Univ. of Illinois, Urbana.

Pask, G. (1975a). *The Cybernetics of Human Learning and Performance.* London: Hutchinson.

Pask, G. (1975b). *Conversation, Cognition and Learning.* Amsterdam: Elsevier.

Pask, G. (1976a). "Conversational Techniques in the Study and Practice of Education," *British Journal of Educational Psychology* Vol. 46, part 1.

Pask, G. (1976b). "Styles and Strategies of Learning," *British Journal of Educational Psychology.* Vol. 46, part 2.

Pask, G., and Scott, B.C.E. (1972). "Learning Strategies and Individual Competence," *Int. J. Man Machine Studies.* 4, 217—253.

Petri, G.A. (1965). "Communication with Automata." Trans. by F. Greene, Jr., A supplement to Tech. Documentary Rep. 1, Rome Air Development Center, Contract AF30(602) 3324.

Phillips, L.D. (1973) *Bayesian Statistics for Social Scientists.* London: Nelson.

Piaget, J. (1962). "Comments on Vygotsky's critical remarks concerning the Language and Thought of the Child, and Judgement and Reasoning in the Child," (issued with ref. to Vygotsky) Cambridge, Mass.: MIT Press.

Piaget, J. (1968). *La Structuralisme.* Trans. by C. Maschler (1971) as *Structuralism.* London: Routledge and Kegan Paul.

Polya, G. (1954). *Mathematics and Plausible Reasoning.* Vol. 1, Induction and Analogy in Mathematics. Vol. II, Patterns of Plausible Inference. Princeton, N.J.: Princeton University Press.

Popper, W.R. (1959). *The Logic of Scientific Discovery.* London: Hutchinson.

Posner, M.I. (1966). "Components of skilled performance," *Science.* 152, 1712—1718.

Poulton, E.C. (1953). "Two channel listening," *Brit. J. Exp. Psych.* 46, 91—96.

Poulton, E.C. (1960) "The optimal perceptual load in a paced auditory inspection task," *Brit. J. Psych.* 51, 127—139.

Prince, G.M. (1970). *The Practice of Creativity.* New York: Collier.

Pringle, J.W.S. (1951). "On the parallel between learning and evolution," *Behaviour.* 3, 174.

Quillian, M.R. (1969). "The Teachable Language Comprehender — a simulation programme and a theory of language," *Communs.* ACM. 12(8) 459.

Rapaport, A. (1972). "Mathematical Theory of Isomorphisms," in *Trends in General System Theory*, Ed. G. Klir. New York: Wiley.

Rescher, N. (1966). *The Logic of Commands*. London: Routledge and Kegan Paul.

Rescher, N. (1973). *The Coherence Theory of Truth*. London: Oxford University Press.

Robertson, I. (1974). "SSRC Report on Project HR 2371/1, Applications and Developments of a Theory of Teaching and Learning." August, System Research Ltd.

Rossman, J. (1964) (revised edition). *Industrial Creativity* (originally printed, 1931). New York: University Books.

Santos, Eugene S. (1970). "Fuzzy algorithms," *Information and Control*. 17, 326—339.

Scandura, J.M. (1973). *Structural Learning*. London: Gordon and Breach.

Scandura, J.M. (1974). *Proceedings, Fifth Annual Interdisciplinary Conference on Structural Learning*. MERGE Institute, Philadelphia, or National Technical Information Service, Springfield, Virginia.

Schon, D.A., (1963). *Displacement of Concepts*. London: Tavistock Publications.

Schwartz, T. (1962). "Palian Movement of the Admiralty Island (1946, 1954)," *Anthropological Papers of American Museum of Natural History*. Vol. 20, Part 2.

Selfridge, G. (1959). "Pandemonium. A Paradigm for Learning," *Proc. International Symposium on Computers and Thought*. London: HMSO.

Simon, H.A. (1973). "Thinking by Computers" and "Scientific Discovery and the Psychology of Problem Solving," in *Mind and Cosmos*, Ed. R.G. Colodny. Pittsburgh, Pa.: Univ. of Pittsburgh Press.

Simon, H.A., and Feigenbaum, E.A. (1964). "An information processing theory of some effects of similarity, familiarisation and meaningfulness in verbal learning," *Jnl. Verbal Learning and Verbal Behaviour*. Vol. 3, No. 5, 385—396.

Spencer Brown, D.G. (1969). *Laws of Form*. London: Allen and Unwin.

Stelzer, J., and Kingsley, E. (1974). "Axiomatics as a paradigm for structuring subject matter," *Instructional Science*. Vol. 3, No. 4, 383—450.

Storm, H. (1953) "Eolithism and Design," *Colorado Quarterly*. 1, 3, Published posthumously.

Strub, M.H., and Levitt, R.A. (1974). "Computer Compatability with Decision Style: Eddies in a Bit Stream," Proceedings: Human Factors Society 10th Annual Meeting, October 15—17, Huntsville, Alabama, pp. 46—49.

Sutherland, N.S. (1964). "The learning of discrimination by animals," *Endeavour*. Vol. XXIII, No. 90.

Tanner, W.P., and Swets, J.A. (1954). "A decision-making theory of visual detection," *Psych. Rev.* 61, 401—409.

Taylor, C.W., and Ellison, R.L. (1964). "Predicting Creative Performance from Multiple Measures," in *Widening Horizons in Creativity*, Ed. C.W. Taylor. New York and London: Wiley.

Taylor, C.W., and Williams, F.E. Eds. (1966). *Instructional Media and Creativity*. New York: Wiley.

Thomas, H.B.G. (1970). "On the Feedback Regulation of Choice Behaviour" *Int. J. Man Machine Studies* 2: pp. 235—266.

Thomas, L.F. (1970). "Kelly-McQuittie; a Computer Programme for Focussing the Repertory Grid." Centre for the Study of Human Learning. Uxbridge, London: Brunel University.

Thomas, L.F. (1971). "Interactive Method of Eliciting Kelly Grids." Paper presented at the Occupational Section B.P.S. Conference, published in *Proceedings*.

Torrance, E.P., and Gupta, R. (1964). *Programmed Experiences in Creative Thinking*. Bureau of Educational Research, University of Minnesota.

Treismann, A.M. (1966). "Our limited attention," *Advert. Sci.* 102, 553; 104, 600.

Tversky, A., and Kahneman, D. (1971). "Belief in the law of small numbers," *Psychological Bulletin*. Vol. 76, No. 2, 105—110.

Tversky, A., and Kahneman, D. (1973). "Judgement under uncertainty. Heuristics and biasses," *Science*. Vol. 185, 1124—1132.

Upton, A. and Sampson, R.W. (1963). *Creative Analysis*. New York: Dutton.

Von Foerster, H. (1971). "Molecular Ethology," in *Molecular Mechanisms of Memory and Learning*, Ed. C. Ungar. New York: Plenum Press.

Von Foerster, H., and Weston, P. (1974). "Artificial Intelligence and machines that understand" *Annual Review of Physical Chemistry* 24.

Von Foerster, H., Inselberg, A., Weston, P. (1968). "Memory and Inductive Inference," in *Cybernetic Problems in Bionics*, Ed. H.L. Oestreicher and D.R. Moore, London: Gordon and Breach.

Von Hagen, V.W. (1962). *The Ancient Sun Kingdoms of the Americas*. London: Thames and Hudson (Panther, 1967).

Wallach, H., and Averbach, E. (1955). "Memory Modalities," *Am. Jnl. Psych.* Vol. 68, 249—257.

Walter, W. Grey (1956). "Studies on Activity of the Brain," in *Cybernetics: Circular, Causal and Feedback Mechanics*, Transactions of 1953 Josiah Macy Jr. Foundation Conference, 18—32.

Walter, W. Grey, Cooper, R., Aldridge, V., McCallum, W.C., Winter, A.L. (1964) "Contingent Negative Variation: an electric sign of sensori-motor association and expectancy in the human brain" *Nature*, 203, 380—384.

Welford, A.T. (1968). *Fundamentals of Skill*. London: Methuen & Co.

Winner, R.I. (1973). "Cartoons; an Initial Investigation of Animated Graphs," School of Information Science Conference, Georgia Institute of Technology, Atlanta, Ga.

Yates, F.A. (1966). *The Art of Memory*. Routledge and Kegan Paul, London.

Yntema, D.B., and Mueser, G.E. (1960). "Remembering the present states of a number of variables," *J. Exp. Psych.* 60, 18—22.

Yntema, D.B., and Mueser, G.E. (1962). "Keeping track of variables that have few or many states," *J. Exp. Psych.* 63, 391—395.

Zadeh, L.A. (1973). "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes." *IEEE Transactions on Systems, Man and Cybernetics.* Vol. SMC-3, No. 1, Jan., 28—44.

Zadeh, L.A. (1974) "A Fuzzy Algorithmic approach to the Definition of Complex or Imprecise Concepts." Electronics Research Laboratory, College of Engineering, University of California, Berkeley.

References added whilst in press:

Varela, F. (1975) "A calculus for self reference," *Int. J. Gen. Syst.* 2: 5—24.

Varela, F. (1976) "The extended calculus of indications interpreted as 3 valued logic," *Notre Dame Journal of Formal Logic.*

Varela, F. (1976) "The Arithmetic of Closure," Proceedings of Third European Meeting on Cybernetics and Systems Research, Vienna.

Goguen, J. (1976) "Objects," *Int. J. Gen. Syst.* 1: 237.

Goguen, J. (1976) "Complexity of Hierarchically Organised Systems and the Structure of Mucial Experience" *Technical Report* in Dept. Computer Science, UCLA.

Subject Index

Graphics display, 67, 74

Name Index