Int. J. Man–Machine Studies (1980) **13**, 357–411

Developments in Conversation Theory—Part 1

GORDON PASK

Systems Research, 16 Montague Rd, Richmond-upon-Thames; The Architectoral Association School of Architecture, London and Brunel University, U.K.; NIAS, Wassewaar, The Netherlands

(*Received 11 October 1979*)

This paper is the first in a series describing developments in conversation theory and related work during the past 8 years.

1. Introduction

Over the last 8 years, since the first account of Conversation Theory was published in this journal, there has been a substantial body of research and the theory has been developed in several ways. This paper is part of a series written in an attempt to bring matters up to date, and to acknowledge related work, omitted in other publications.

Amongst the developments is a recognition that the theory, about conversations between human beings as participants, or between several coherent and stable perspectives in one human brain, refers to more phenomena than originally supposed (i.e. sharp valued and observable psychological events). It proved desirable, on the one hand, to import the stability or autonomy criteria of organizational closure (Maturana, 1975; Varela, 1975; Von Foerster, 1976*a*, *b*) and on the other hand, to model agreement by a procedural extension of Rescher's (1973) coherence truth.

The result is that Petri type information transfers, interpretable as varieties of consciousness, become evident in the system and appear in a conceptual process at those points where consciousness (by someone, A, with someone, B, *of* something), or even awareness (*of* A, or *of* B, alone), are reported, in practice. Such transfers are bound to take place in any coherent dynamic system when the algebraic structure of a Turing Machine [or some liberalized variant, such as an "Occurrence System", Holt & Commoner (1972)], is *not* imposed upon a piece of hardware. Stochastic models, with comparable mathematical roots, obscure the phenomena, when they are used descriptively since the transfers in question are manifest only as the local synchronization of *a priori* asynchronous processes or the desynchronization of an *a priori* synchronous (thus, coherent) colection of processes. It should thus be emphasized that the transfers in question, interpreted here as varieties of consciousness, will be evident in any theory which regards a brain and mind as made up from populations of possibly interacting dynamic units. If these interactions are treated as transactions, (rather than stochastically, as types of statistical complex), then the same characteristic will be manifested.

It is, however, an important and non-trivial characteristic to have in a formal theory; the price paid is some doubt as to whether such a theory (although, indisputably, formal), is a strictly mathematical theory. This open question is currently being examined by Gergely, Nemeti, Andreka and their colleagues (for example, Markusz & Szots); it is also in the province of recent work by Byshovsky (1974), Flores & Winograd

0020-7373/80/080357+55 $02.00/0

(1978), Goguen (1975), Varela (1976) and Von Foerster (1971, 1976*a*, *b*). The conclusion that is reached (strictly mathematical or not, and if so, how) should apply, with equal cogency, to theories of objects, memories, descriptions, and comparable entities which have been proposed, independently, during the interval under review, by Glanville and his colleagues (Glanville, 1975, 1979; Glanville & Jackson, 1977), and have been developed in some measure mutualistically, as complementary representations.

These features of Conversation Theory together with some global consequences are described in this paper. Another generalization is fairly recent and will be described in a later paper. The entailment meshes, which form the background or epistemological frame of reference, for conversation theory were previously regarded as open to growth engendered by a language user who may make them evolve. Certain transformation rules governed the permissible extrapolations of an entailment mesh: but, previously, these had been regarded as grammatical, or, in some cases, semantic, regulations. About a year ago, it became evident that there is a primitive language system (it is called a protolanguage, Lp), which underlies all potentially coherent entailment meshes, (Pask, 1979*b*, *c*). Although Lp is very crude, it is dynamic; its refinements could serve as "language" in the social sense (either of written or spoken language, of architectural, or technical, or poetic language), a language which is inherently dynamic and in a state of evolution. "Language" users may, incidentally, employ "language" to communicate with each other, but, primarily, they modulate some refinement of Lp. Such matters are being studied by Pedretti (1979), in terms of linguistics, and by Robinson (1979), in terms of sociology, as independent, complementary and largely mutualistic, developments. The arguments presented later are primarily concerned with Lp, rather than its refinements (Pedretti, 1979).

A later paper will provide a summary of the empirical support for Lp and Conversation Theory in part built up during the 8 years under scrutiny and in part from the literature on creativity, problem formulation, innovation, design, problem solving, etc. The latter enquiry sets the psychological foundations of conversation theory in the tradition of Bartlett (1932), Duncker (1945), Luria (1968) and Wertheimer (1961), connects it to the position of both Piaget (1968) and Vygotsky (1962), [to some extent to the "Personal Construct" psychology of Kelly (1955)]. The most interesting neurophysiological concommittents are Popper & Eccles (1977), Brown (1977), Easterbrook (1978) and the pioneering research on "Abscission" by Walter (1953, 1969). At the level of social psychology, there are many links to work by Braten (1977, 1978) with Herbst or Buber, and Moscovici (1976).

2. Conversation Theory

Apart from seminar presentations in Illinois, Vienna and Zurich, a programme for research, "Conversation Theory", was first published in this journal. The idea is outlined in Pask (1972), and stems, in part from earlier work on adaptive and self-organizing man/machine systems [summarized in Pask (1972) and Lewis & Pask (1969)]. Including the 1972 overview, there are five papers (Pask & Scott, 1972; Pask, Scott & Kallikourdis, 1973*a*, *b*; Pask, Kallikourdis & Scott, 1975) which cover various aspects of the theory, the man/machine interfaces, such as CASTE (Course Assembly System and Tutorial Environment) used to model the theory or perform experiments,

and the framework relative to which the theory is proposed, namely structures of related topics known as entailment meshes and conversational domains.

Other statements of this theoretical position and methodology are Pask (1975*b*, 1976*c*), which form, between them, a fairly comprehensive statement, as well as several specialized papers, for example, Pask (1976*a*, *b*). The background and an introduction to the study is given quite fully in Pask (1975*a*) which bridges the gap between Pask (1961) and these publications. There are several excellent independent statements and appraisals of Conversation Theory, notably, Daniel (1975*a*, *b*) and Entwistle (1976, 1978).

Conversation Theory, henceforward simply CT, has been developed and refined during the intervening years and a substantial body of supportive evidence exists, sufficient to give a cluster of interlocking hypotheses claim to the title "theory". It has not been necessary to discard any of the original tenets but there have been changes of emphasis and of convenient notation. These changes are chiefly due to substantial generalizations; for example, Organizational Closure has been introduced as a stability and autonomy criterion, the notion of agreement is fully stated as a procedural extension of coherence truth (as amongst a set of propositions), Petri type information transfer is established as the form of transaction and essential bifurcations are shown to arise in a conversation as well as being resolved by agreement between the participants.

This paper in the series is mostly concerned with the conceptual processes influenced by these generalizations and updates CT, in this respect, with the minimum repetition needed for an intelligible presentation. The baseline for the discussion is the original form of CT, which identified a conceptually sharp valued (or "hard") datum, namely, an agreement over an understanding between the participants in a conversation. Sharp (or "hard") observations of events like responses need not be, and frequently are not, sharp or "hard" conceptual events; rather, sharp or "hard" conceptual events are symbol valued behaviours, that index agreement over an explanation of some commonly pointed out topic together with agreement and a justification (or explanation of why the explanation was chosen). As a result of these agreements, it is argued that a concept, regarded as a productive and reproductive process, is shared by the participants and forms part of their mental repertoire.

The participants, in question may be interviewer and respondent, a Piagetian experimenter participating with a subject, a student and a teacher; also, since more than one point of view can coexist in one person, it is possible to exteriorize and observe normally hidden transactions between coherent points of view or perspectives. The original form of CT details the conditions which must be satisfied in order to assure an external observer that an agreement over an understanding has taken place, and presents a construction (in retrospect, rather a clumsy one), that unifies the representation of stable concepts, perspectives, participants and conversations between them.

3. Preliminaries

L is a language; either a natural language, or a system of symbolic behaviours such as mime, or gesture, or actions like pointing at images and key pressing. L *may* be formalized, provided that many qualities of a natural language are preserved, notably, competence as a vehicle for commanding, questioning, and expressing metaphors that designate analogies. L *must* be well enough specified to convey interpretable instructions.

3.1. L PROGRAMS

Prog is an L program; namely, a series of instructions, interpretable by an L processor. In this context, a program does not necessarily mean an algorithm, with the usual properties of serial execution, partial correctness and termination. It is possible to select L programs that satisfy these canons, but *Progs* need not, and, in general, do not, do so. They are, however, executable "heuristics". Parallel execution is permissible, hence the heuristics may either be deterministic, or possibilistic-Fuzzy, (Gaines, 1976; Zadeh, 1974, 1978).

3.2. COMPUTING MEDIA

An L Processor is a computing medium, a deliberately noncommittal word. Human brains, and the neural sensory and motor apparatus, are biological computing media. But, however beautifully adapted to this function, they are not the only ones. Nor are computing media necessarily biological.

3.3. SHARING OR EXTERIORIZING MENTAL OPERATIONS

Many L programs are executed partly in one brain and partly in peripheral apparatus, neural or not. For example, there is a task, (Pask *et al.*, 1976–79) employed for studies of decision making in complex systems, where a human decision maker controls two vehicles able to perform operations such as manoeuvring, action taking and obtaining or searching for information in a dynamic environment, which consists in an allegory of "space". The vehicles are invariably controlled by tactics (sequences of up to 20 "if . . . then . . . or else" statements, pertinent to the environment), and the tactics form an interface between the human decision maker and his environment, of which the vehicles are a part. Under these circumstances, processes which would normally be executed in the brain are, in fact, exteriorized for execution by the vehicles, in their sensory (information search) or motor (manoeuvre and action) roles. Viewing the situation in the reverse direction, the ordained tactics are executed *on* behalf of human decision makers *by* the vehicles.

Very much more specific interfaces have been used, in establishing CT, to externalize specific types and sequences of cognition as observable behaviours (for example, CASTE, (Pask, Scott & Kallikourdis, 1973*a*, *b*), or EXTEND, (Pask, Kallikourdis & Scott, 1975), INTUITION, (Pask, 1976*a*), in the THOUGHTSTICKER system, which incorporates CASTE and is outlined, later, in the present discussion). Verbal interchange, monitored by rather strict acceptance criteria have also been employed (Pask, 1972), or mixed systems with verbal dialogue, but mechanically recorded explanation of a data base (Pask, 1975*b*, 1976*c*).

At the other extreme, there are plenty of common situations that promote less regulated exteriorization of mental activity. For instance, people with vastly different brains share L programs, whenever they converse, part being executed in one brain, and part in the other. Similar comments apply to the mutualistic control of intelligent animal behaviour probably the most impressive evidence of man/animal (or animal/man) interaction is Hendrix's account of horse training (in Bateson, 1972).

3.4. THE GENERALITY OF COMPUTING MEDIA

Brains and special artifacts, like vehicles with tactics, do not seem to occupy a specially privileged position. An embarrassingly large number of concrete systems can, potentially, accept and execute sequences of L instructions; notably, physical systems studied macroscopically, but far from equilibrial conditions, for example, systems removed by several "cascaded" bifurcations from the equilibrial mode (Nicolis & Prigogine, 1977). Specific, and highly relevant special cases have been studied using computer simulation, by Nicolis & Protonotarios (1978). These "dissipative" media could execute L programs and must be countenanced as *candidate* L media, which implies that the arguments of this paper, primarily advanced in the context of brains, cognition, and the like, are, in fact, very general.

3.5. TENDENCY TO COHERENT PROCESS EXECUTION

One ubiquitous feature of all competent L computing media is that they are not constrained to a serial mode of operation, if only because devices able to handle L expressions must accommodate analogy. The converse, but just as salient characteristic, is that all of them have, through one mechanism or another, a tendency to coherent execution of L programs (i.e. conflict free parallel operation, in contrast to concurrency, which may entail conflict between simultaneous processes). Phrased differently, if several L programs are compiled for execution, then the resulting operations are usually incompatible, unless there is information transfer between them. In a medium which tends to coherence, the information transfer due to incompatibility leads to a recompilation of the L programs so that the system tends towards (although it may or may not reach) parallel operation in which no further information transfer is *needed* between the procedures under execution.

The mechanisms which mediate coherency between originally incoherent processes may be of many kinds, for example, phase locking and the entrainment of non-linear oscillators (section 3.4). At *this* point it is only necessary to note that coherent execution can *always* be achieved, however improvidently, in a computing medium that consists of as many *a priori* independent parts, or single processors, as there are L programs for execution.

3.6. FUNDAMENTALS

There are several very commonly used words which have a taken-for-granted, and not-to-be questioned, status. As a rule, this status is quite helpful; it would be a nuisance to ask the meaning of addition or multiplication (say), whenever these operations are used. But the expedient of taking-for-granted leads to trouble when dealing with rudimentary, though profound, ideas; when, in fact, one is dealing with the nature of the entities that *are* taken for granted.

This paper does, of necessity, explore such a territory. Amongst the words which *must* be examined in detail, even though their meaning is usually glossed, are "information" and "process" and "independence".

3.7. PROCESS, INFORMATION AND INDEPENDENCE

A process is the activity of a general (concurrent) Petri net. "Information" is also used in that context. Petri's (1964) information transfer is a fundamental notion, closely related to the idea of the pioneer information theorists, but, only in an indirect fashion, to the quantification schemes of information theory; it is the quality or commodity, indicated by the "quantity of information". Holt (1968, 1972) provides a general discussion but, for the present purpose, "information transfer" is either (a) or (b) below:

(a) the *appearance* of synchronicity between several, otherwise asynchronically clocked, systems, to provide a time, common to the systems, perhaps locally evident; or

(b) the *appearance* of dependence between several, otherwise independent systems, during a standard (Newtonian) time interval (and perhaps, temporarily).

Independence, unqualified, means complete independence and of any kind whatsoever as for example, temporal or spatial. Upon qualification it becomes a specific type of independence.

Agreements take place between distinct or independent systems.

The ideas of time, of synchronicity, as a time common to several systems, of independence, and of information transfer, can be traded off and interchanged in various ways. It will be convenient, in this paper, to characterize the notion of *process*, by means of *independence* and *information transfer*, noting however, that independence means *complete* independence.

3.8. STABILITY

Serious consideration of commonly taken-for-granted ideas of independence and process brings the classical notion of stability into question; that is, stability as a static dynamic, periodic, or metastable, regularity of behaviour represented as a trajectory, in a fixed descriptive framework, selected as canonical by an external observer, which constitutes the system's structure.

For the conceptual systems of primary concern there is no obvious, or at any rate, immutable, distinction, between structure and behaviour. An appropriate unit of study turns out to be an entity which is productive and which reproduces its own structure (perhaps with variations), as part and parcel of its activity (its behaviour).

This type of stability was introduced in the initial formulation of CT, as "P Individuation", but "P Individuation" is a particular (cognitive) manifestation of a more general and mathematically elegant idea "organizational closure". In the sequel, "organizational closure" is taken as the canonical stability criterion and the classical modes appear as special cases of it. The *stability*, or literally, *autonomy* of organizational closure is *exemplified* by mechanisms that are organizationally closed, in the body of the paper.

Notably, systems that are organizationally closed (alias, autonomous), tend to the coherent execution of section 3.5 without prejudice to the possibility that organizationally closed systems may also be (as in section 3.7) informationally open.

4. Participants and procedures

Let A, B, . . . stand for participants, in an L conversation, indexed by Z = A, B, ... Temporarily, it is useful, and not misleading, to think of participants as "L speakers"; $Prog_A$, $Prog_B$, . . . are programs that "belong to" A, B, . . . (form part of A's, B's, . . . repertoire), and "*Ex*" means "Execution of".

4.1. EXECUTION OF PROCEDURES

The statement "*Ex* (*Prog*)" is, as it stands, meaningless.

This statement would be sensible in computer science, where a class of computers is assumed to (and does) exist. But, in the present case, such an assumption is improper, since the "computers" in question are frequently brains, or other "computing media" that are specified only with respect to their "hardware" and not, as in the domain of computer science, by a specific algebraic structure. To accommodate the difference between computing machines and the hardware of a general computing medium, natural or artifactual as the case may be, each L program is paired with a compilation, or kinetic interpretation, written, $Inter_A$, $Inter_B$, . . . , for the region of the computing medium in which it is executed as an L process.

A pair $\langle Prog_A, Inter_A\rangle$ is called a *procedure* or *Proc* and the statement *Ex* (*Proc*) does make sense. Since *Prog* has the form of an executable heuristic (section 3.1) *Ex* (*Proc*) is interpreted as the indefinite iterative execution of *Proc*.

4.2. NAMES AND DESCRIPTIONS

Let upper case letters like P, Q, . . . , R, . . . , S, T stand as *names* for descriptions and also to avoid a great deal of indexing, for *descriptions*, as such.

For example, T may stand for *circle* or T may stand for *driving*. There are indefinitely many compatible descriptions of circles; for instance, rules for classifying geometrical figures, or exemplary collections of figures, probably with counterexamples (that an octagon is not a circle and an ellipse becomes one, only as a special case). There are innumerable descriptions of driving, as well; some characterize the attributes of driving and others are exemplary collections of behaviours.

Some descriptions are in terms of others. Possibly *all* descriptions have this form. Certainly, such descriptions invariably exist. For example, "T (circle) is a figure formed by rotation of a compass (P), its origin at any point on a plane (Q) and having any radius" or T (driving) is a "coordination of steering, signalling, engine management and observation".

In general (and I do not know of any real exceptions) descriptions are fuzzy, insofar as many congruent descriptions coexist under one name, and may, if desired, be assigned an index of compatibility (Zadeh, 1978) as their grade of membership in a relation (for example, a relation between points on a plane surface or segments of behaviour).

Finally, a description is obtained by executing one or more procedures, that maintain or satisfy the relation described.

4.3. PROCEDURES AND DESCRIPTIONS

If $Prog_A$ T is a program which is used by participant A, to compute, control, achieve or maintain a relation T, then the compilation of $Prog_A$T, for A, is an ordered pair, namely the *procedure*

$$\langle Prog_A\mathrm{T}, Inter_A\rangle = Proc_A\mathrm{T},$$

which may be executed to yield a description

$$Ex\ (\langle Prog_A\mathrm{T}, Inter_A\rangle) = Ex\ (Proc_A\mathrm{T}) \Rightarrow \mathrm{T}_A,$$

where T_A is A's description of an entity, T, or A's behaviour conforming to T. Without prejudice to other possibilities (that T_A is a "Behaviour" that T_A is "an oscillation or waveform"), T_A is *sufficiently* specified in the input and output domain of $Prog_A$T embodied in $Proc_A$T.

For example, let $Inter_A$ be a tesselation plane of two state automata, constrained by a Conway neighbourhood rule (Conway, 1970). Let $Prog_A T$ be an initial pattern. Let $Proc_A T$ be the initial state configuration upon the tesselation plane. Let *Ex* mean the application of the rule to produce successive generations, so that T_A is the stable configuration of states on the plane. In general, $Ex\ (Proc_A T) \Rightarrow T_A$ means that T_A is the class of fixed point values of the (non-linear) transform $Proc_A T$ (that T_A is the class of eigenvalues of the eigenoperator(s) $Proc_A T$).

4.4. PROCEDURES, INTERPRETATIONS AND INDEPENDENCE

In general, different compilations of an L program give rise to different descriptions. So, if A and B are distinct participants, then

$$Ex\ (Proc_A T) = Ex\ (\langle Prog\ T, Inter_A \rangle) \Rightarrow T_A,$$

$$Ex\ (Proc_B T) = Ex\ (\langle Prog\ T, Inter_B \rangle) \Rightarrow T_B,$$

and T_A is, at the *most*, isomorphic "$\Leftrightarrow$", to T_B; certainly $T_A \neq T_B$; in general, $T_A \supseteq T_A{}^* \Leftrightarrow T^* \Leftrightarrow T_B{}^* \subseteq T_B$ where the common part, T^*, may vanish.

Within any one participant, there may be independent regions of the computing medium, say X and Y, written AX, AY, for A and BX, BY, for B. For example, there may exist procedures

$$Proc_A K = \langle Prog\ R, Inter_{AX} \rangle,$$

$$Proc_A L = \langle Prog\ S, Inter_{AY} \rangle,$$

$$Proc_B M = \langle Prog\ R, Inter_{BX} \rangle,$$

$$Proc_B N = \langle Prog\ S, Inter_{BY} \rangle,$$

$$Ex\ (Proc_A K) \Rightarrow K_A, \quad Ex\ (Proc_B M) \Rightarrow M_B,$$

$$Ex\ (Proc_A L) \Rightarrow L_A, \quad Ex\ (Proc_B N) \Rightarrow N_B,$$

$$K_A \neq L_A \neq M_B \neq N_B \quad \text{and} \quad R \neq S,$$

but

$$K_A \equiv R_A, \qquad M_B \equiv R_B, \qquad L_A \equiv S_A, \qquad N_B \equiv S_B.$$

Noting that any of the "*" marked common terms may be void, there is a possibility of making comparisons between and within the participants.

Between the participants, A and B:

$$R_A \supseteq R_A^* \Leftrightarrow R^* \Leftrightarrow R_B^* \subseteq R_B,$$

$$S_A \supseteq S_A^* \Leftrightarrow S^* \Leftrightarrow S_B^* \subseteq S_B.$$

Within each participant, if U^* stands for the common part (possibly void) of $R_A^* \Leftrightarrow S_A^*$ and V^* for the common part of $R_B^* \Leftrightarrow S_B^*$, the following relations hold between independent subprocesses in the computing medium "of" A and "of" B:

$$R_A \supseteq R_A^* \Leftrightarrow U^* \Leftrightarrow S_A^* \subseteq S_A,$$

$$R_B \supseteq R_B^* \Leftrightarrow V^* \Leftrightarrow S_B^* \subseteq S_B.$$

If R^*, S^*, are *not* void there may be, in a weak sense, an *agreement* between A and B; if U^*, V^*, are *not* void there may be an analogy relation (alias, a weak kind of agreement), between the independent parts X, Y, of A or of B. These "parts" AX, AY, of A are called perspectives of A and the "parts" BX, BY, are called perspectives of B, to be identified, in the sequel, with points of view that A, B, may adopt.

4.5. DIFFERENCES BETWEEN DESCRIPTIONS

Ultimately, P, Q, . . . , R, . . . , S, T, are given different names, so that circles are distinct from octagons, and driving is considered distinct from walking or flying because there are cases in which the common parts R^*, S^*, are not empty and U^*, V^*, have a smaller measure than either of them. [One could, but I shall not, have recourse to the (to us obvious) fact that circles and octagons are different objects, that driving, walking and flying appear as different behaviours.] Rather, an explanation is offered in terms of A, B, agreements, reached by A, B, communication and this begs the question of why communication should take place.

Once again, one could answer this question by recourse to the (to us obvious) benefits, of cooperation, in social systems. Very likely this *is* a multiple causative factor. A sufficient answer is obtainable, however, by postulating the existence of L *Progs* which can be compiled and executed in $Inter_A \times Inter_B$ (the Cartesian Product), but neither in $Inter_A$, alone, nor $Inter_B$, alone, regardless of whether that is due to the particular advantages of social interaction.

The greater capability of "$Inter_A \times Inter_B$" is neither only, nor primarily, a matter of "storage capacity" which is obviously greater than the capacity of $Inter_A$ or $Inter_B$ or (in some appropriate sense) their union. The existence of a *distinction* and an abstract cooperation between distinct parts is of critical significance.

Similar comments apply to the construction of analogies, or internal agreements, where some L program can only be executed in $Inter_{AX} \times Inter_{AY}$ or $Inter_{BX} \times Inter_{BY}$, (from section 4.4). In order to execute such programs more than one perspective or point of view must be adopted, simultaneously, by A or B.

For example, the independent portions, X, Y, of the computing medium may be identified (amongst many other identifications) with the visual and the tactile modalities. Either modality, alone, provides an ambiguous representation of the environment. For instance, the retinal image is a 2-dimensional projection of an infinite number of 3-dimensional entities. Tangible objects owe their perceptual reality to co-operation between procedures proper to the visual and the tactile sense modalities. [Gregory (1970), who stresses this perceptual problem, rightly calls the procedures "hypotheses".]

4.6. DESCRIPTIONS AND THE PROCESSES GENERATING THEM

In a computing medium, such as one human brain, or a collection of several human brains coupled by linguistic dialogue, or by a computer regulated interface (section 3.3) there are, by hypothesis, procedures undergoing execution. Thus, at any moment, the following entities exist in the system of A's repertoire, or B's repertoire:

$$Proc_A T, Proc_B T, \ldots$$

and the result of their execution which may be embodied in the computing medium connecting to the input/output domains of the *Progs* (just as *Progs* are compiled as *Procs*):

$$Ex\ (Proc_A T) \Rightarrow T_A,\ Ex\ (Proc_B T) \Rightarrow T_B, \ldots$$

By a deliberate although plausible artifice, it has been arranged that the question "on what operands do *Procs* operate?" can be answered, without prejudice to other possibilities, as "*Procs*", or "Descriptions, *Ex* (*Proc*)*s*".

Since an operation (upon such entities) may be initiated before, after or during the execution of a given *Proc*, it is necessary to recognize, as limiting cases of operands, *Proc* and *Ex*(*Proc*), or to speak of *Operators*, alias *Procs*, that act upon these limiting case operands, distinguished as *Op* 1, *Op* 2 (say) *Proc* = *Op* 1, such that

$$Ex\ (Op\ 1\ (Proc, \ldots Proc{:}\ Ex\ (Proc) \ldots Ex\ (Proc)) \Rightarrow Proc$$

Proc = *Op* 2, such that

$$Ex\ (Op\ 2\ (Ex\ (Proc) \ldots Ex\ (Proc)) \Rightarrow (Ex\ (Proc)).$$

To avoid a great deal of index complexity, it will again be expedient to concentrate upon special cases, and simply bear in mind that each type of entity (*Proc*, or *Ex* (*Proc*)), may appear in arbitrary numbers in the operands. So *Ex* (*Op* 1) is rendered

$$Ex\ (Op\ 1(Proc_A P,\ Proc_A Q,\ T_A)) \Rightarrow Proc_A T{:}\ Ex\ (Proc\ T_A) \Rightarrow T_A.$$

Similarly, *Ex* (*Op* 2) is rendered

$$Ex\ (Op\ 2\ (Ex\ (Proc_A P),\ Ex\ (Proc_A Q)) \Rightarrow T_A = (Ex\ (Proc_A T)).$$

Of these limiting operator types, *Op* 1 is known as a procedure building, or *PB*, operator and *Op* 2 is known as a description building, or *DB*, operator. The remaining possibility

$$Ex\ (Op\ (Proc \ldots Proc)) \Rightarrow \text{Combination of } Procs$$

is not excluded, but appears to have the quality of an unspecific, ongoing activity.

It is, for example, easy to identify *Op* 1 with a macrogenerator, assembling *Procs* under the "goal" of satisfying (for instance), T_A and *relative* to this description (or "goal"), such that *Ex* (*Proc* T_A) = T_A; *Op* 2, the description building operators, which carry descriptions like P_A, Q_A into other descriptions (T_A) were identified, in the original formulation of CT, with *relational* operators (for example, *join*). Apart from convenience, there is no reason for such a specific identification.

In contrast, a "combination of procedures" could be any combination whatsoever which results in an executable procedure. Even very unrestrictive evolutionary systems, for example, Fogel, Owens & Walsh (1966), contain "goal statements" responsible for selectivity and, unless they *did*, it is hard to see how they could be *described* (which is not, of course, to deny their existence).

4.7. INDETERMINACY

The empirical evidence, especially from detailed studies of the learning process, for example, Luria (1961, 1968), Entwistle (1976), Entwistle & Hounsell (1975), our own studies, some using complex exteriorizing methods or the work of others, summarized in Pask (1977), appears to warrant the following conclusions:

(a) That all people have brains that are provided with operations at *least* able to act *as* the *DB* and *PB* operators.
(b) That no two people think alike (there is *no* possibility of saying *exactly* how they perform), and much the same comment often applying to one person in two contexts, if these are apprehended differently.

A basic indeterminacy in the possible observations is (clearly) asserted by clause (b), and it is important to notice that this is *not* an indeterminacy of the kind where the interior of a "Black Box" is inaccessible. Depending upon the circumstances, a "Black Box" indeterminacy may, or may not, exist; regardless, *this* is *not* the limiting indeterminacy. The point is that even if it *were* possible to scrutinize the activity, say of a brain, in arbitrary detail it would be irrelevant from a conceptual stance (in the sense of language, thought, meaningful action, a psychological stance), to do so. Beyond limits of the type set in clause (a) or its refinement, any attempt to be more specific over the "substrata", multiple cause, or the "how is it done", of a *particular* thought serves only to abrade or corrupt the phenomenon under scrutiny; literally, to render the process no longer a *conceptual* process. The essential issue is that much more is being stated than "thinking is very complex", or "thought processes are ineluctable unless we probe more deeply".

5. Concepts as units

In general philosophy there is a standard and (necessarily) defensible usage of *concept* namely, the meaning of a word. In psychology and linguistics there is little accord, and less concern with precision in the matter. Probably it is agreed that *concepts* are pretty ubiquitous, (like consciousness, for example, which is also a forbidden subject). Some lip service is paid to both of them but, however important, they are both surrounded by a great deal of sloppy thinking; and serious attempts to discover what on earth is intended by either tend to be brushed aside (covertly, for the most part) as gratuitous theorizing.

Some authors, a little outside the mainstream movements, *do* use the term concept, non-trivially. Schon (1963) for example, deals with the displacement of concepts, rightly identifying this process as a component of innovative acts. Festinger (1972), in his theory of cognitive dissonance, correctly identifies concepts as being either consonant or, under some conditions, generators of dissonance. But these theories are macroscopic, and neither claims to say what a concept *is* though a moments scrutiny is enough to show that it is neither an impressed pattern, nor a storage location in some cerebral engine, nor an "association" (whatever that means nowadays) of ideas, reflexes, sense data, or whatever, it is popular to "associate".

Of course, there are many psychologists and linguists who do take the matter of mental unities quite seriously (in contrast to the hodge-podge of patterns, and storage locations, which suit a prevailing climate of opinion). But they are wise enough to avoid disputation by giving their unities different names, whatever the idiom they speak. For example, Hebb (1949), in the idiom of neurophysiology, refers to "phase-sequences". Bartlett (1932) in the arena of eclectic functionalism, to "schemata"; Kelly (1955) invented the happy neologism, "personal construct" to stand for such a thing. Duncker

(1945), and later Wertheimer (1961) used the terminology of problem solving in much of their work, but the notional under pinning alludes to concepts, as such.

More recently, Bruner (1974), Newell (1973), Newell & Simon (1972), Simon (1973), Simon & Newell (1971), Norman *et al.* (1975), Scandura (1973, 1975), and some of the other cognitive psychologists, have reinstated "concepts" as no longer taboo. But, with due respect, concepts are reincarnated in a diluted form. One feature, common to the serious attempts to identify a mental unity, the *procedural* aspect of a concept is preserved intact, but the procedures envisioned resemble the procedures executed by present generation computers too closely for realism. The other aspect common to Schemata, Phase sequences, Personal Constructs, or *Concepts* (in an other-than-trivial sense), is that they are productive and reproduced, or constructive and reconstructed.

"Concept" has given rise to contention and misapprehension in the field of CT where, from the outset, the word has designated a mental unity. It would, perhaps, have been more prudent to choose a different word; for surely, psychologists and linguists avoid the term for *some* good reasons; for example, they are loath to engage in hair-splitting arguments with philosophers, and are quite happy to be told (by the philosophers, like Kollers, who address them), that *their* concepts are really a species of "connotation *of*", namely, "subjective intensions" (presumably, in the sense of Martin's (1963) brilliant, though difficult to digest, analysis of intensions generally).

When writing this paper, I considered making a revision but concluded that in all honesty, no change of position was needed. I mean "concept" in the philosopher's sense, with the sole (and hardly objectionable) caveat, that not all "meanings" are named by words; I also mean "concept" in the sense of an organization which belongs to a participant A, or B, . . . , which is reproduced and productive in the repertoire of that participant, as well as in the amalgam of individual repertoires achieved by conversation between the participants (of whatever kind, people, perspectives or institutions), that make up the totality of a culture (or *all* cultures and civilizations past, present, or future, concrete or imagined). Since that, and nothing less than that, is intended, "concept" is used with propriety, and the following section of the paper is a statement of what I believe stable (permanent rather than evanescent) concepts to *be*.

5.1. CONCEPTS AS SKILLS (BARTLETT'S PARADIGM)

A concept is a skill (usually intellectual), and consists of a collection of wholly, or partially, coherent procedures.

First, define a fully coherent (or conflict-free-parallel) collection, as the square-bracketed term.

$$[Proc_{\mathrm{A}}\mathrm{T}].$$

More accurately, since there are many $Proc_{\mathrm{A}}\mathrm{T}$, distinguished by an index i, able to compute, or satisfy, $\mathrm{T_A}$

$$[Proc^{i}_{\mathrm{A}}\mathrm{T}].$$

5.2. DEFINITION THROUGH PROCEDURES

A concept, $Con_{\mathrm{A}}\mathrm{T}$, is defined recursively, with "{ }" an unordered collection, as

$$Con_{\mathrm{A}}\mathrm{T} \triangleq Proc_{\mathrm{A}}\mathrm{T} \quad \text{or} \quad [Proc^{i}_{\mathrm{A}}\mathrm{T}] \quad \text{or} \quad \{\{Proc_{\mathrm{A}}\mathrm{T}\}, [Proc_{\mathrm{A}}\mathrm{T}]\},$$

such that execution produces a description or behaviour:

$$Ex\ (Con_{\mathrm{A}}\mathrm{T}) \Rightarrow \mathrm{T_A}.$$

Further, the execution of any *Proc* in *Con* produces this description, or behaviour. For $Proc_{\mathrm{A}}(\mathrm{T})$ in $Con_{\mathrm{A}}\mathrm{T}$; $Ex\ (Proc_{\mathrm{A}}\mathrm{T}) \Rightarrow \mathrm{T_A}$.

The relation "in *Con*" means "coherent upon execution", not, for example, set membership "$\in$", or inclusion "$\subset$", hence, the deliberate use of *in*.

5.3. INTERNAL INFORMATION

So, for a given computing medium, a concept is a wholly or partially coherent system of productions, the coherence of which may or may not involve information transfer.

In the limiting cases of a concept, namely $Con_{\mathrm{A}}\mathrm{T} = Proc_{\mathrm{A}}\mathrm{T}$ (one procedure) and $Con_{\mathrm{A}}\mathrm{T} = [Proc^{i}_{\mathrm{A}}\mathrm{T}]$ the execution of $Con_{\mathrm{A}}\mathrm{T}$, does *not* involve an information transfer. On the other hand, in all remaining cases when $Con_{\mathrm{A}}\mathrm{T} = \{\{Proc_{\mathrm{A}}\mathrm{T}\}\ [Proc_{\mathrm{A}}\mathrm{T}]\}$ the integrity and stability (in fact, the autonomy) of $Con_{\mathrm{A}}\mathrm{T}$ does involve an information transfer between procedures undergoing execution.

5.4. STABLE CONCEPTS

The concepts we know and name (*a fortiori*, the concepts that many philosophers regard as the meaning of words in a language, but also, which count as personal connotations or subjective intensions) are *stable* (memorable, not merely evanescent, permanent constituents in a scheme of beliefs).

So what, in this context, is stability? Importing the *DB* and *PB* operators of section 4 (and ordain they are of type *Con*) to define the connection "in *Con*" to form a closed system of productions (as a more precise statement of the "productive and reproduced" character of concepts, already discussed).

The arrangement is grossly but globally depicted in Fig. 1; in greater detail, in Fig. 2 (for $Con_{\mathrm{A}}\mathrm{T}$, a component of participant A's repertoire) and in Fig. 3, for $Con_{\mathrm{B}}\mathrm{T}$ and thus a component of B's repertoire. The production schemes are free production

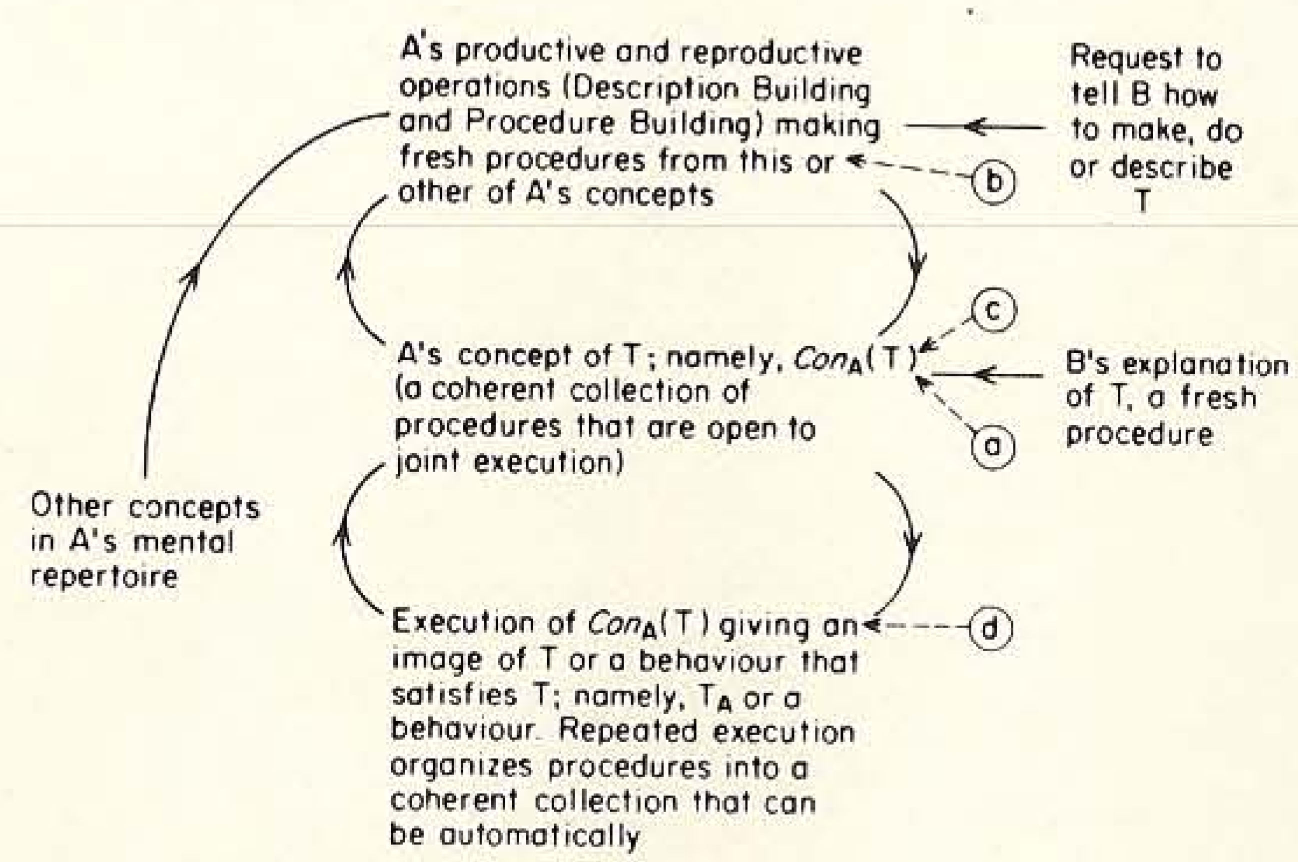


FIG. 1. Global picture of organizationally closed stable concept, $Con_{\mathrm{A}}\mathrm{T}$ of a participant A regarding a topic $\mathrm{T_A}$. The letters a, b, c, d, are used only at a later stage in section 9 and may be neglected until that point is reached.

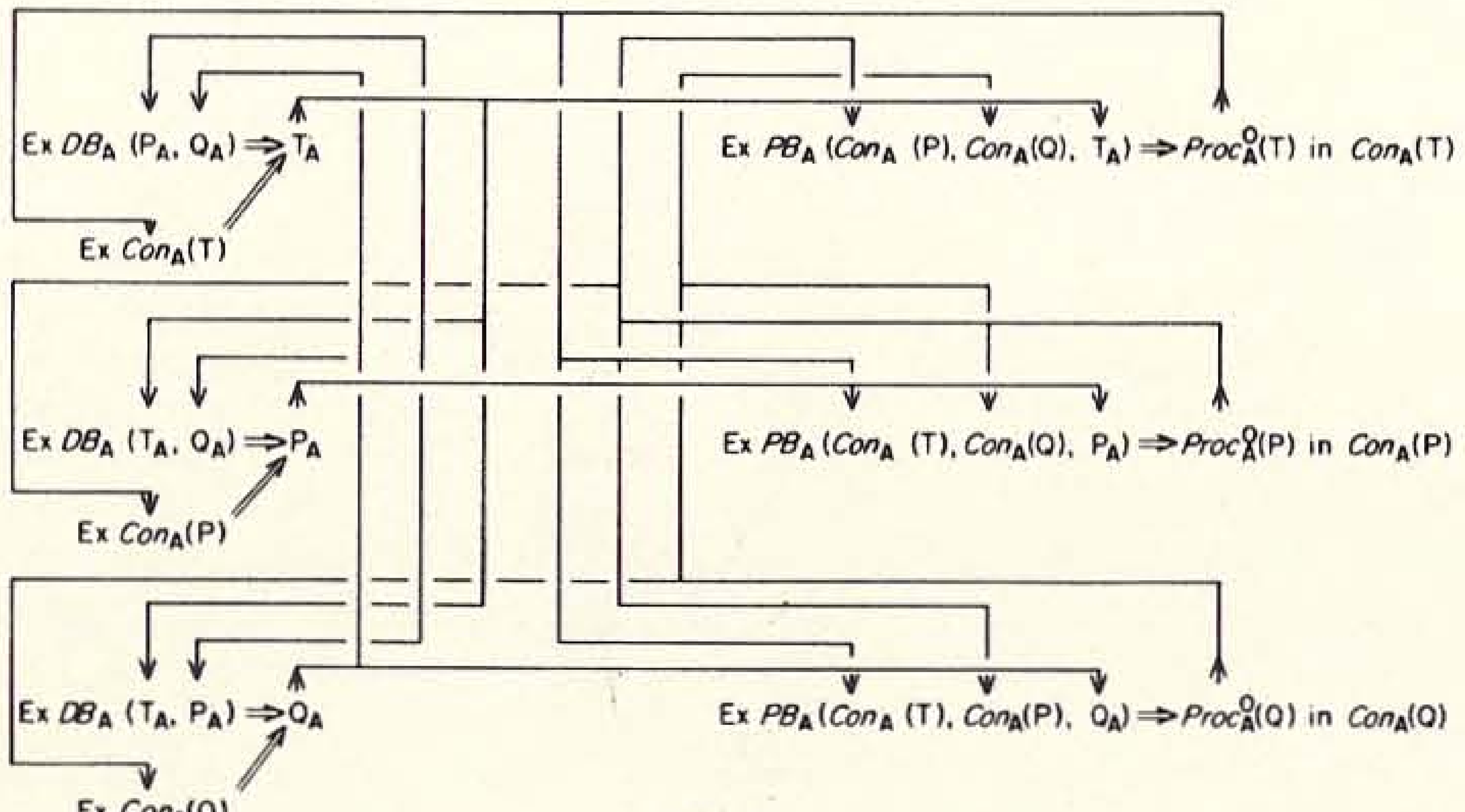


FIG. 2.

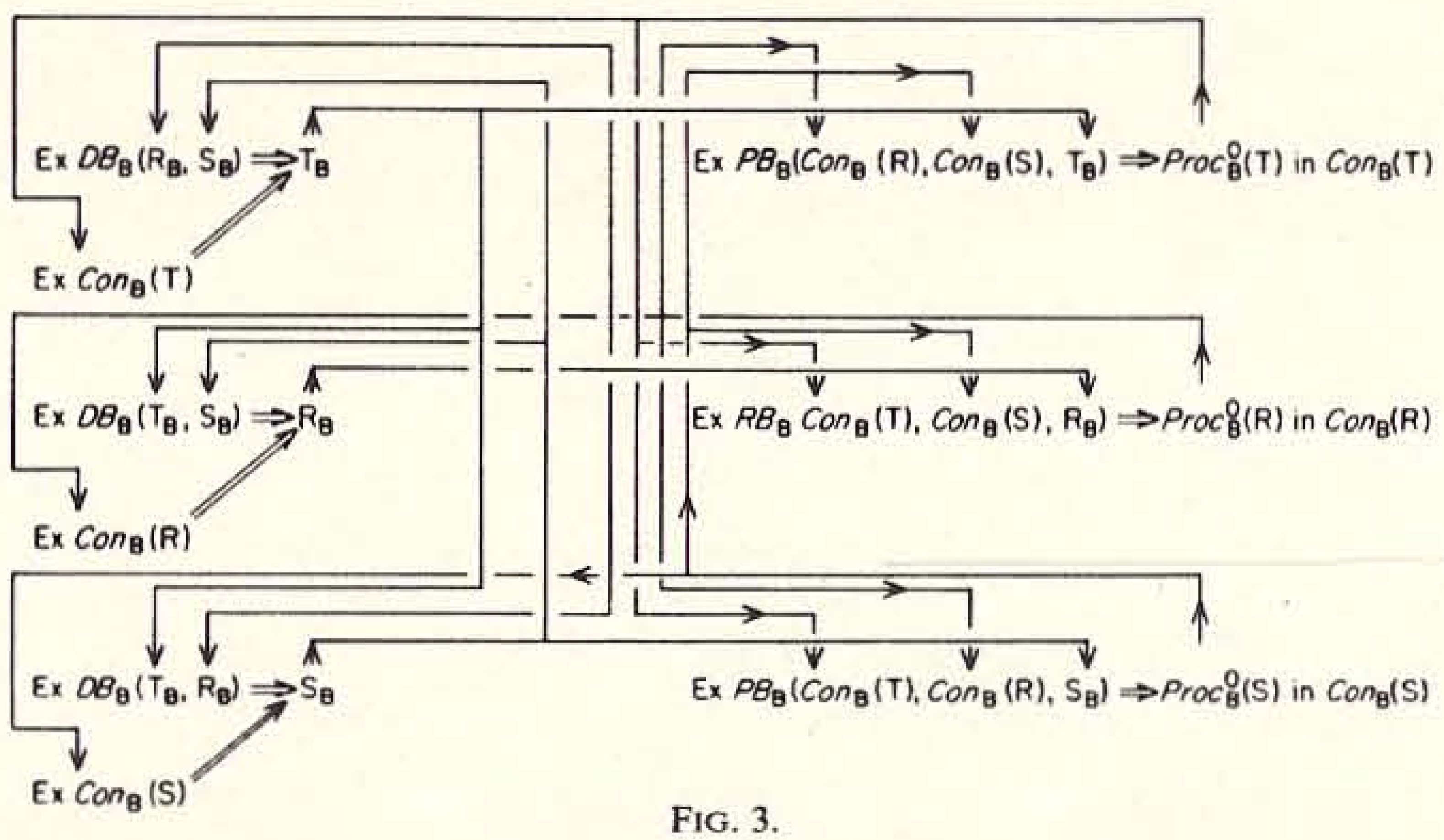


FIG. 3.

systems, meaning that the control of execution is built into the system by including over and above the productions, "$\Rightarrow$", return loops, shown as "$\rightarrow$", through which products (namely, *Procs*) are returned as parts of the *corresponding* operands. The system is asynchronous, except for the local synchronicity achieved by virtue of process execution; the order which is induced if this Petri-net like closed system of productions are made to act.

Because of interior control the free production schemes differ quite significantly from the production schemes proposed by Howe & Young (1976), Klahr (1977) and others. Again, although there is considerable similarity (in some cases identity) between Scandura's "Rules" and the *Procs* of CT, there is a fundamental difference in the formulation of a "stable concept". In Scandura's (1973, 1975) "Structural Learning Theory", the controller responsible for applying rules, resides, explicitly, *outside* the basic unit, for CT it is *inside* the unit.

Conversely, because these properties *are* introduced, the closed, free production systems of CT (stable concepts) have a form of stability, more precisely of autonomy, (stability being a special case of it) called "organizational closure", by Maturana (1975), Varela (1975) and Von Foerster (1976*a*). The criterion of organizational closure was first employed by Maturana in Biology and neurophysiology, where it is known as "Autopoiesis". When exploited, in the field of cognition, sociology, or other spheres, it is expedient to use "organizational closure" as a systemic quality, having no particular biological overtones.

5.5. ORGANIZATIONAL CLOSURE OF STABLE CONCEPTS

Figure 2 is interpreted as A's concept (Con_AT) of T_A, say of a circle, which (following the suggestion in section 4.2) is derived from A's concepts of a compass (P_A) and a plane surface (Q_A). Figure 3 makes B's concept Con_BT of a circle, T_B, deliberately different. B conceives circles in terms of R_B and S_B where, plausibly, R_B may stand for a world of cylinders having various radii, and S_B as an instrument capable of making infinitesimal slices through any cylinder in this world.

In both cases, the closure or autonomy of stable concepts is due to an ordering or synchronization of processes which entails information transfer within the system, given the indefinite iteration of *Ex* (section 4.1). It is immaterial whether this internal transfer is regarded as between the productive and reproductive operations (*DB* and *PB*), or between the *Procs* in *Con*; as in section 4.5, the difference reduces to a question of ordering. Continued execution gives rise (section 4.2) to stable values T_A, P_A, Q_A or T_B, P_B, Q_B and to the generation of further $Proc_A$s that produce these descriptions when executed (for example, $Proc^i_A$T, $Proc^j_A$T . . . , $i \neq j$). The tendency to coherent execution in a computing medium (postulated in section 3.5), requires that *Procs* that are generated become recompiled, as a result of continual execution with (internal) information transfer so that the entire system approaches a condition in which execution is *parallel* and no (internal) information transfer is needed to obtain coherence. The *degree* of stability at any point, depends upon the number of methods (*Procs*) available for achieving the same result, equivalently upon the redundancy of the computation performed in a coherent mode, or upon the number of *Procs* that belong to [$Proc^i_A$] in Con_A.

The schemes, as they stand, neither assert nor deny (external) information transfer, between Con_AT and some other autonomous unit. Some organizationally closed systems are, and some are not, informationally open. But, for any participant (say A) at least some *must* be open, in order to manufacture DB_A, PB_A, as ingredients [for example, Ex(Op$_1$(Con_AP, Con_AQ, T_A)) $\Rightarrow PB_A$ not in Con_AT: Ex(Op$_1$(Con_AP, Con_AQ, T_A)) $\Rightarrow DB_A$ not in Con_AT].

6. One easily realized demonstration of an organizationally closed system

A useful demonstration of organizational closure and one image of a stable concept is obtained by identifying "indefinite iterative execution" of *Proc* (section 4.1) with "turning on a non-linear oscillator" and identifying "a description" (section 4.2) with the "characterizing waveform" of this oscillator. The identification is perfectly legitimate, provided oscillators and waveforms are taken in the intended fashion, as *one* example of a *general* phenomenon. Keeping that caveat in mind, the following sequence, Fig. 4, Fig. 5, Fig. 6, demonstrates the synthesis and stabilization of the organization $Con_A T$.

Figure 4 and its caption contain the initial *supposition* (which must be eliminated in the course of the demonstration). It is assumed that procedures $Proc_A P$ and $Proc_A Q$ exist, as compiled programs or oscillators, from which a code (*Prog*), can be read off and

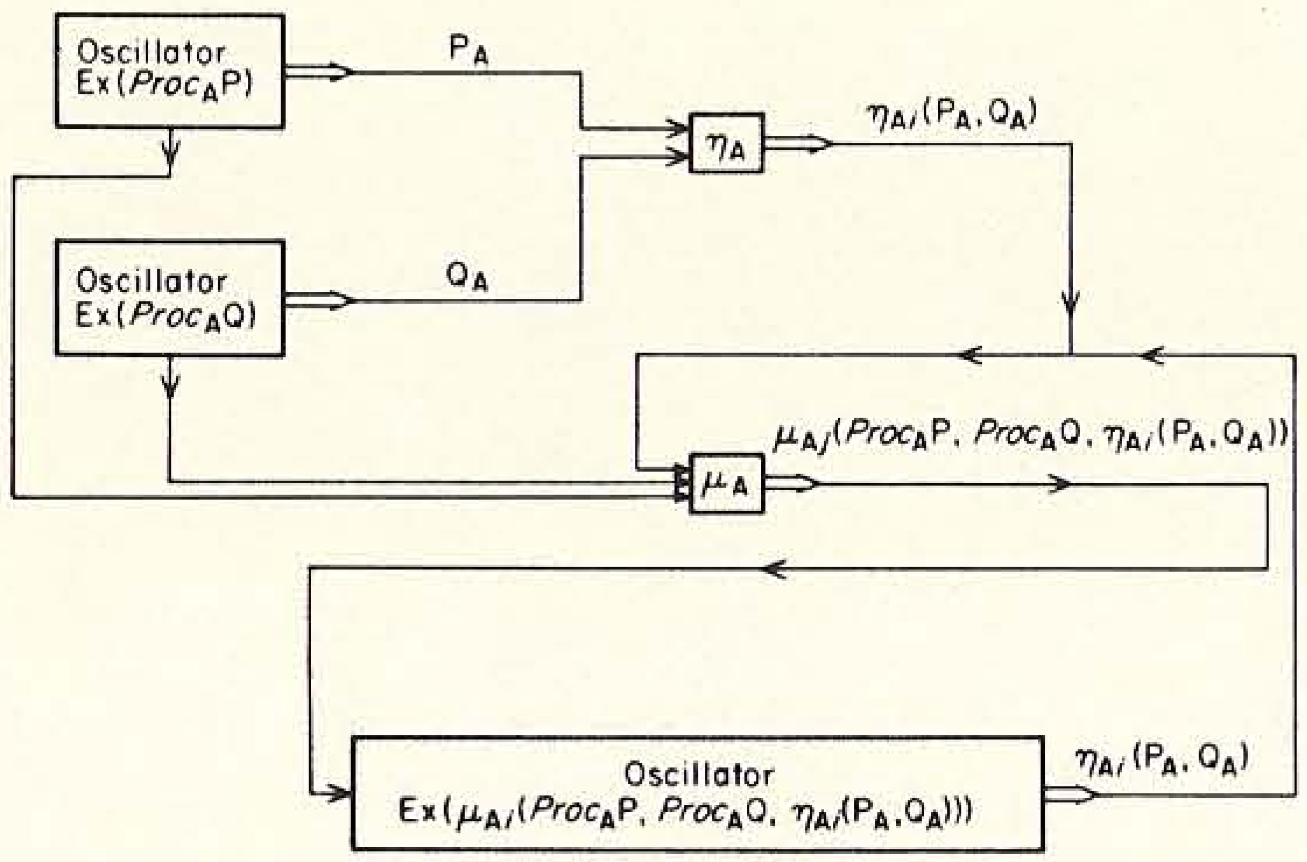


FIG. 4. It is assumed, initially, that oscillators (corresponding to the indefinite iteration of $Proc_A P$ and $Proc_A Q$ in distinct processors) exist, and are turned on, to emit waveforms P_A and Q_A (the descriptions computed by $Proc_A P$ and $Proc_A Q$).

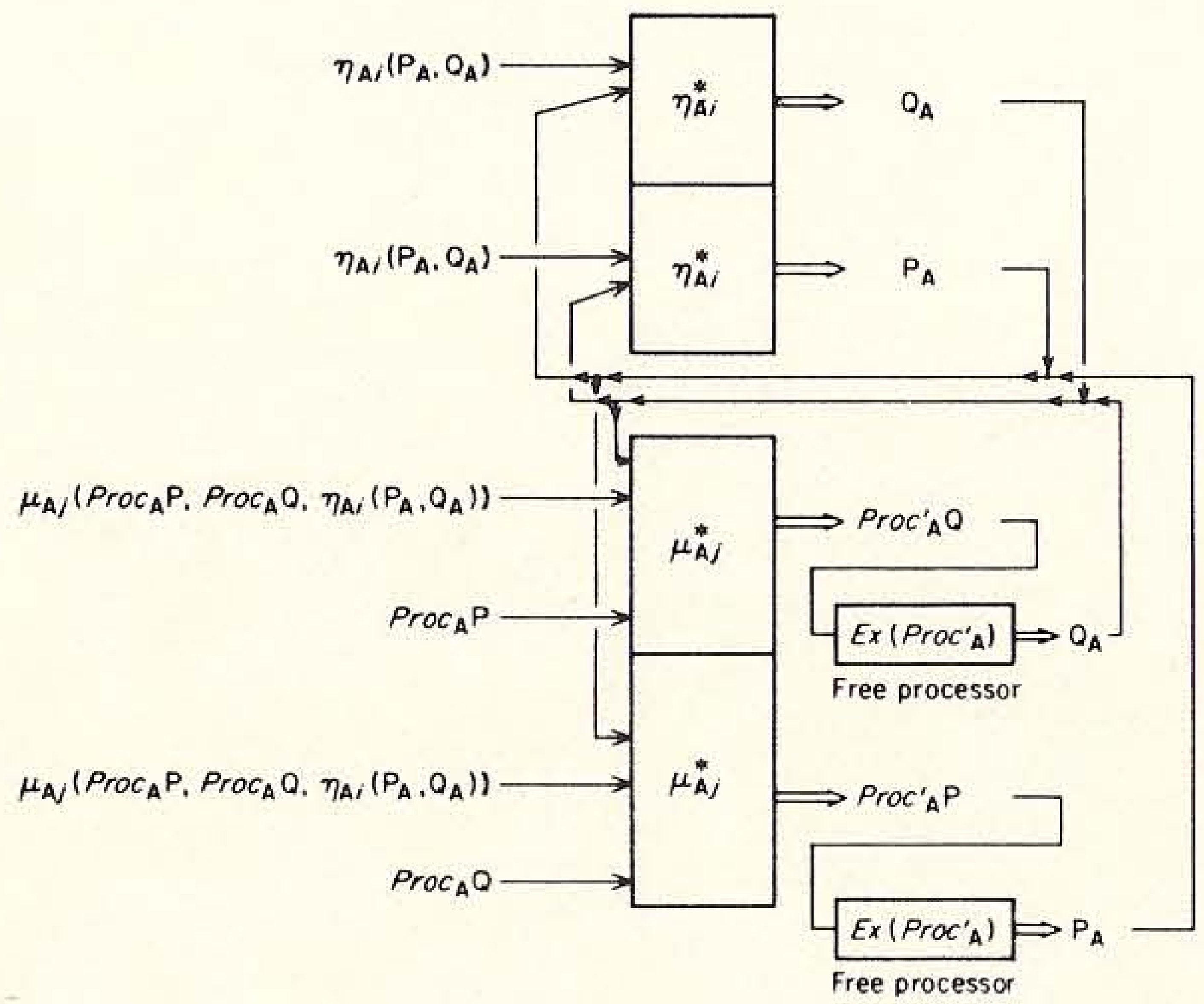


FIG. 5.

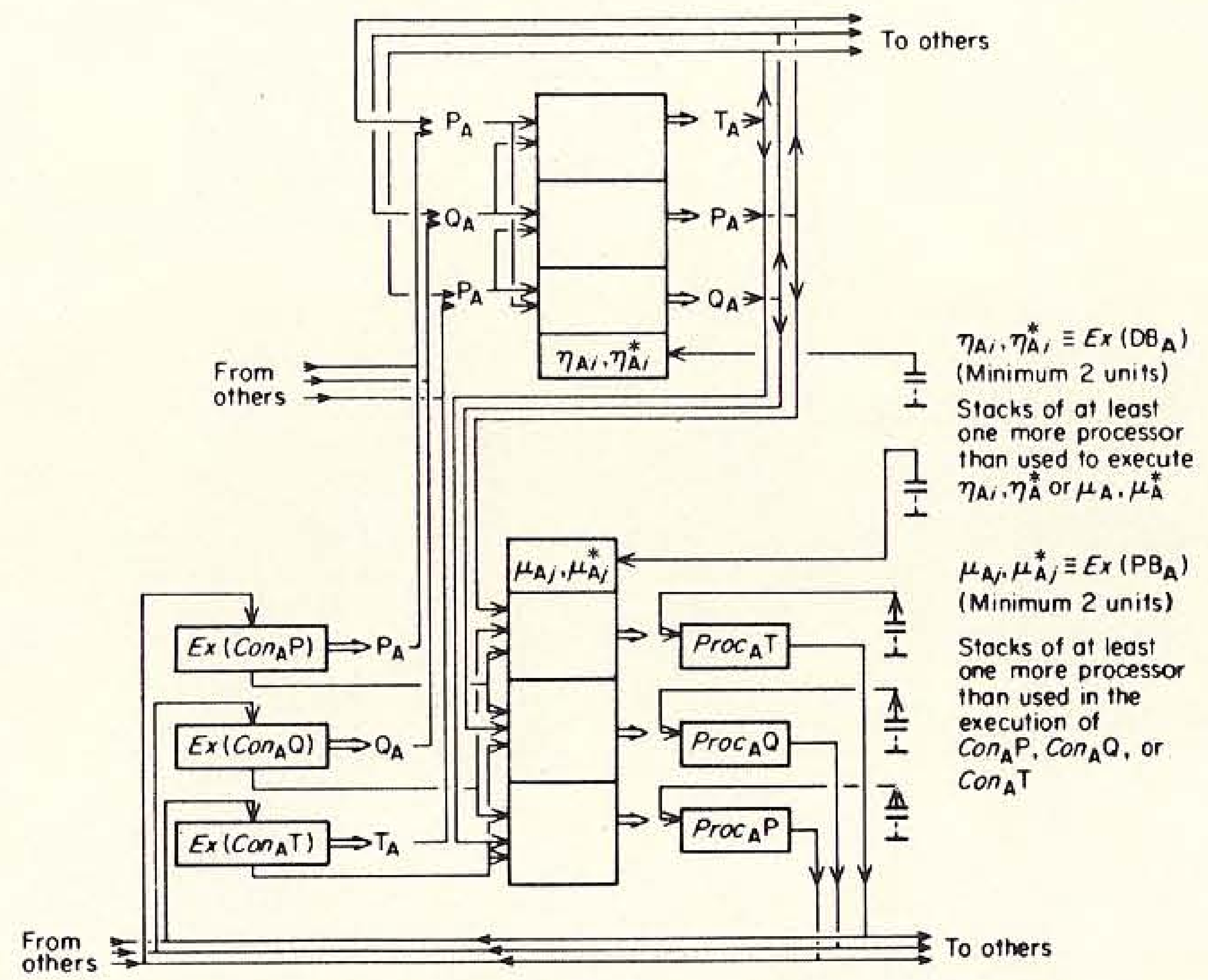


FIG. 6. System of oscillators for a stable concept model. One implementation of production scheme, better realized by a partly synchronized collection of machines, such as an array processor with initially asynchronous modules.

which (because they are assumed to exist), emit steady state waveforms P_A, Q_A, when they are executed, or *turned on*.

Let them exist (conveniently, provide two active delay lines, with gain, and positive feedback. Give each of them two parameters, for lag, as their "program".) Observe the waveforms P_A, Q_A generated on an oscilloscope. Combine the waveforms, in almost any way desired (though the operation "join" is bound to make the demonstration work), through η_i, where the value of i is the combination selected. Next read their "programs" $Prog_A P$, $Prog_A Q$ (via an A/D convertor) and (via a D/A convertor), set the parameters of an *independent* oscillator (i.e. "programme" it), so that its output is in resonance with η_i, (P_A, Q_A), the combined waveform. Let a computing device search for a value of j, in μ_j, with the property that μ_j $(Prog_A P, Prog_A Q) = Prog$?, such that Ex $(Proc$?$) = Ex$ $(\langle Prog$?, $\bar{I}nter_A\rangle)$ is in resonance with η_i (P_A, Q_A), where $Inter_A$ is the independent, but hitherto not parameterized, oscillator. Ex $(Proc_A?)$ emits a steady state waveform that is distinct from P_A or Q_A (since $\eta_i(P_A, Q_A) \neq P_A, Q_A$).

Figure 5 shows the next requirement, that an oscillator that produces a waveform P_A can be "programmed" in *another* independent unit by adjusting the unit's two parameters as a function of $Prog_A$? and $Prog_A Q$; that yet *another* independent oscillator can be programmed as a function of $Prog_A$? and $Prog_A P$, by adjusting its two parameters to emit Q_A; if so, the initial assumption has been reconstructed and need no longer be *assumed*, i.e. $Proc_A P$ and $Proc_A Q$ *do* exist.

Figure 6 is the final step in the demonstration. $Proc_A$? can be called $Proc_A T$, and the waveform it emits can be called T_A, distinct from either P_A or Q_A, insofar as the entire system operates coherently, expressing waveforms P_A, Q_A and T_A, any of which may act as a dominant mode; for this purpose, allow for weak interaction coupling the, previously independent, oscillator pairs.

The demonstration is, in one sense, trivial, but it avoids a great deal of the complicated mathematics needed to approximate this state of affairs as the generation of a "random phasor" from other "phasors" locked into partial synchronicity. In practice, mathematical approaches tend to be confusing; partly because their complexity is not needed in this context, and partly because the formal techniques of approximation obscure, as "random", the information transfer and interaction which are placed in the foreground by demonstrating a process, and that constitutes the essence of organizational closure in a computing medium.

7. Agreement over an understanding in CT

When CT was originally formulated, it aimed to detect sharp valued psychological events. These are called "understandings" as a technical, but not perverse, usage of a commonplace term. In particular, such events could be observed in "agreements over understandings" between participants A and B, in conversation; for preference, by transactions *through* (not *with*) an appropriate interface.

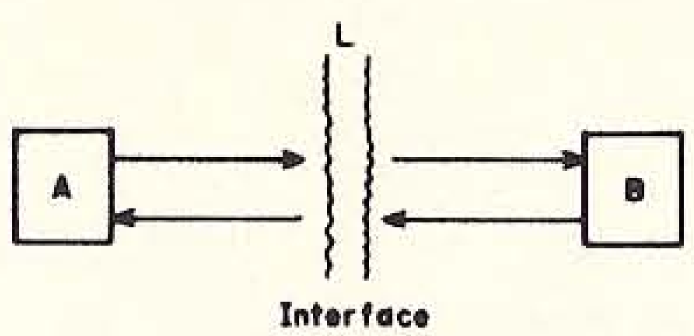


FIG. 7. An L conversation between A and B through an interface.

Figure 7 shows the situation concerned, at a gross level, on a par with Fig. 1. Participant A and Participant B both point at something, "T", which (following the previous interpretation), they refer to as a circle.

A descriptive agreement (and in the limit, a purely ostensive agreement) was mooted as part of the discussion in section 4.3, but "agreement over an understanding" means more than that, and more is needed to mark a sharp valued psychological event.

7.1. ORIGINAL FORMULATION

According to the original formulation of CT (which is still valid in its own right), A and B are required to exchange and justify explanations of how (either intellectually, or in concrete terms), they make T's; here, circles. One paradigm is a verbal (or "Teach-back") criterion; another involves A and B providing distinct working models which upon execution, yield (what they both agree to be) T's, or circles. For example, A and B might write, debug, and trial execute circle drawing programs, in distinct processors (one to A, one to B); the programs are explanations; the result of the exchange is an *understanding* if, subsequently, A is able to write B's type of program as well as his own, and if B is able to write A's type of program, as well as his own.

This activity is summed up in Fig. 8 on the assumption that A and B *do* reach "agreement over an understanding of T".

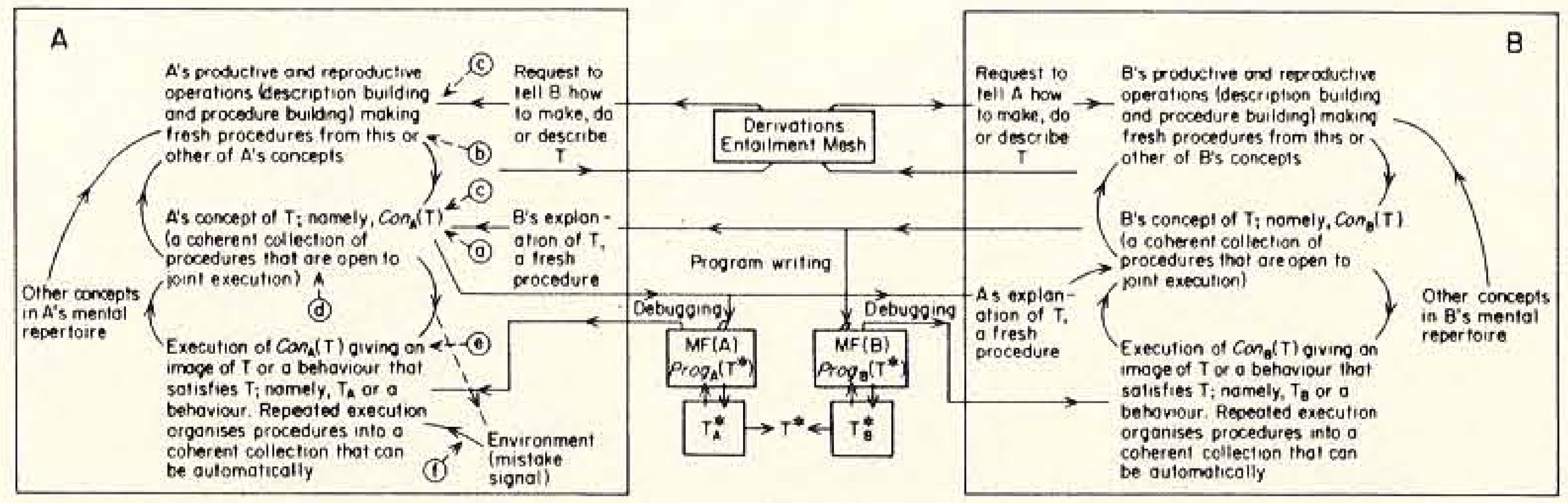


FIG. 8. An L interface for exteriorizing the conceptual events of an L conversation on Topic T. Between participants A and B; MF(A), MF(B) represent modelling facilities or external processors. Derivations are inscribed in an entailment mesh (section 1).

7.2. A GENERALIZATION

In general, agreement over an understanding takes place if A can accept, produce, and reproduce, components (*Procs*) of a stable concept belonging to B (that is, Con_BT), and if B can accept, produce and reproduce *Procs* that are components of Con_AT.

Consider the following possibilities of AB interchange.

(a) A and B have (nearly) isomorphic concepts of T; that is, A builds Con_AT yielding T_A, from concepts of P_A, Q_A and B builds up Con_BT, to yield T_B from concepts of P_B,Q_B. Similarly, in this case, A and B are in substantial accord over T (or, as an alternative statement, T_A and T_B give the same meaning to A and to B).

(b) A has a concept Con_AT but B has none. Under these circumstances, a conversation between A and B places A in the role of teacher, who may program B (using demonstrative explanations, perhaps). Formally, some $Proc_A$T in Con_AT are presented as L expressions $Prog_A$T, and accepted as L expressions, $Prog_B$T, by B, who is a learner. Here, the predictable prerequisite is that B has, or is given, some *DB* operation, able to yield a T_B (but not, as yet, a Con_BT); from descriptions, of whatever kind, in his own repertoire; B may learn insofar as some of the *Prog* T comprising A's demonstration of T will, upon execution by B, as $Proc_B$T, yield T_B, such that T_A matches up to T_B.

(c) Both A and B have concepts of T, but, (as in Figs 2 and 3), they are entirely different. By "circle" A means something different from what B means. Even so, A and B may share their meaning, by sharing programs that are coherent with their (dynamically entertained) stable concepts, so that both A's and B's concepts of circle are enlarged.

Of these possibilities, (c) is clearly the least tractable case, and is examined as paradigmatic.

7.3. ORGANIZATIONAL CLOSURE OF UNDERSTANDING

As in section 4.3 an appropriate criterion of agreement between A and B in Case (c), involves *some*, not *all*, meanings of a topic (T^*, common to T_A and to T_B). Let Con_AT and Con_BT be defined as they are in Figs 2 and 3; let T be pointed at by the participants. A builds Con_AT of T_A (his circle) from concepts of P and Q (compass, plane); B builds his concept Con_BT, of T_B, from concepts of R and S (cylinders and slicing machine). An agreement over an understanding of T requires a local synchronization between process execution in A and in B, so that procedures able to produce T^*, P^*, Q^*, R^*, S^*, are produced and are reproducible in (hence, that they are coherent with) the existing $Con_A T$ and the existing $Con_B T$, of Figs 2 and 3. Just as the partial descriptions are indicated by asterisks, so are the stable subconcepts that generate them (for example, by $Con_A T^*$, $Con_B T^*$, . . . and so on).

The coupled or locally synchronous system that represents the *process* of agreement over an understanding of T^* is shown in Fig. 9. The observable requirements are that Progs are exchanged, as L expressions, between A, B, until

$$T_A \supseteq T_A^* \Leftrightarrow T^* \Leftrightarrow T_B^* \subseteq T_B$$

$$\left\{\begin{matrix} P_A \supseteq P_A^* \Leftrightarrow P^* \Leftrightarrow P_B^* \\ Q_A \supseteq Q_A^* \Leftrightarrow Q^* \Leftrightarrow Q_B^* \end{matrix}\right\} \quad \text{part added to stable concept in B}$$

$$\text{part added to stable concept in A} \quad \left\{\begin{matrix} R_A^* \Leftrightarrow R^* \Leftrightarrow R_B^* \subseteq R_B \\ S_A^* \Leftrightarrow S^* \Leftrightarrow S_B^* \subseteq S_B \end{matrix}\right\}$$

The *result* of reaching an agreement over an understanding of T, is the commonly shared, free, closed, production system of Fig. 10, co-existing in A and in B who can *both* construct *and* reproduce T^* by their old methods or the shared method.

Agreement over an understanding of T^* *is*, precisely the organizational closure of an L conversation between A and B, regarding T^*.

CT maintains that this is the least guaranteed-to-be-sharp-valued psychological event which can be observed; further, that if this event *is* observed then (with considerable empirical support), the shared concept *is* stable (memorable, relatively uninfluenced by interference).

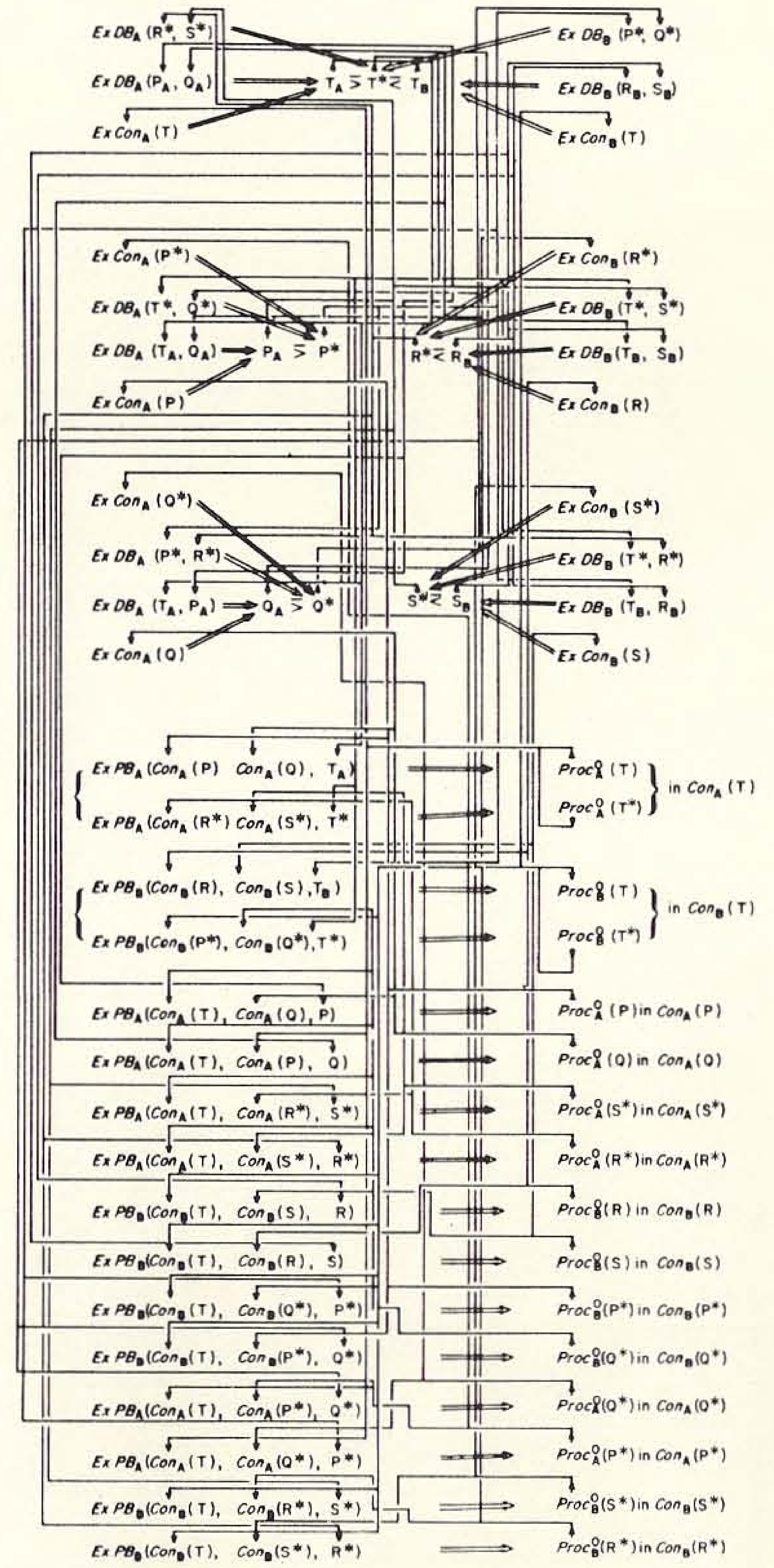
For minimality, Figs 2 and 3 represent collective derivations which may be represented in a shorthand as $T_A(P_A, Q_A)$ or $T_B(R_B, S_B)$ and carry the implication that only one derivation of T_A is recognized by A (however, it entails *all* of the components $P_A, Q_A \ldots$) and only one derivation of T_B is recognized by B (again, it entails *all* of the components $R_B, S_B \ldots$). The argument of Fig. 10 symbolizes a distributive form which may be represented in shorthand as $T^*((P^*, Q^*), (R^*, S^*))$ meaning that some or all of the collective components are entailed by T^*.

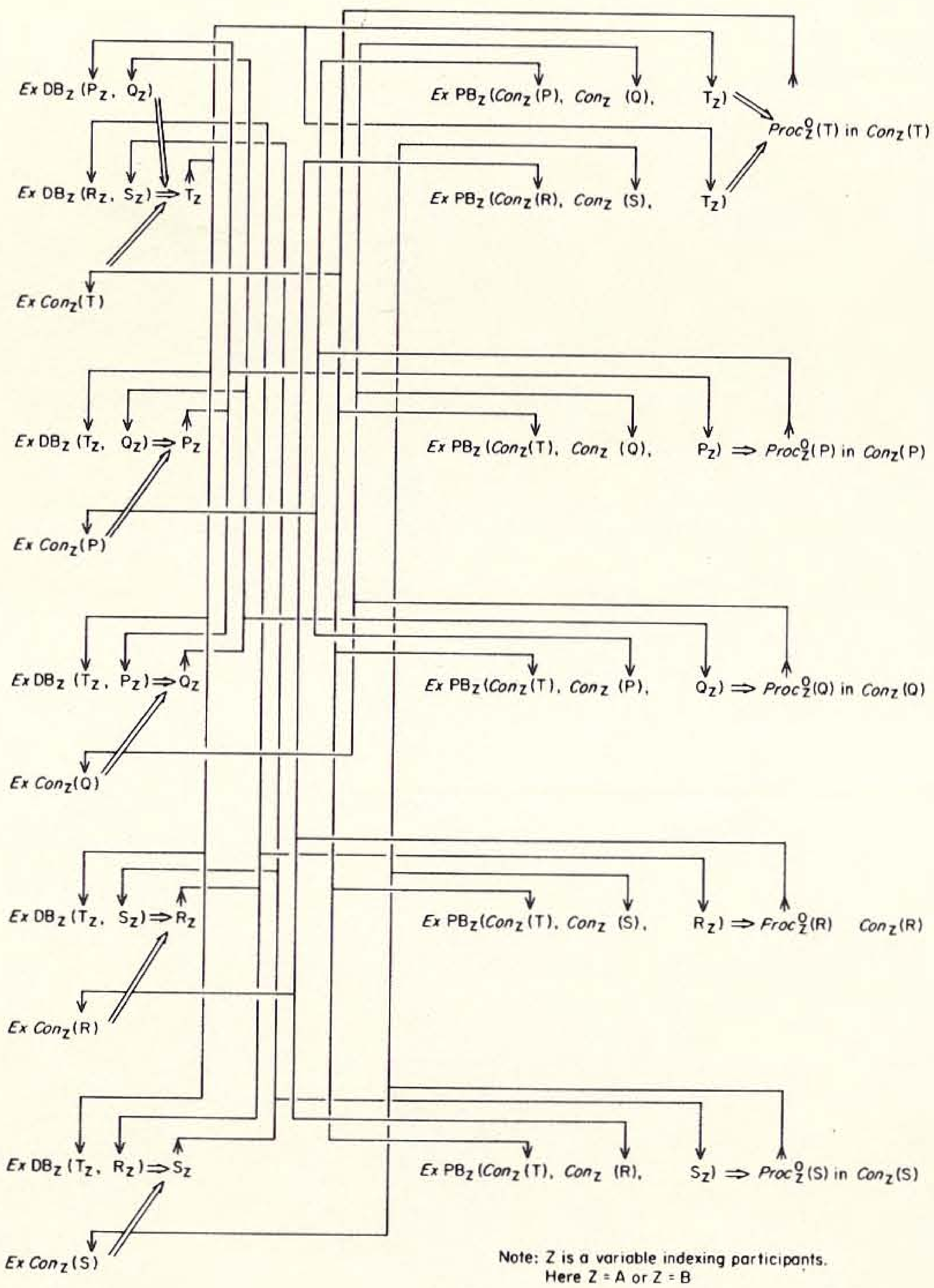
It is perfectly true that agreement over an understanding does *introduce* distributive forms; however, it is essential to notice

(a) That agreements may take place between *already* distributive forms, when several collective entailments are recognized in each of the participants.

(b) That, the organizational closure of a stable concept implies that fresh methods, derivations or whatever are assimilated into the closure and *might* be recognized as distinct (for are assimilated by internal agreement) even though Figs 2 and 3 assert that these methods or derivations are *not*, in fact, recognized as distinct, i.e. the production of distributive forms is *given* as part of the definition of a stable concept although it is *recognized* in terms of agreements between stable concepts entertained by participants.

FIG. 9. L-agreement over common understanding of Topic T. A derives T from P and Q. Participant B derives T from R and S. An agreement may be complete or partial depending upon the isomorphic part (for example, T^*) of topic and the similarity of method.





Note: Z is a variable indexing participants.
Here Z = A or Z = B

FIG. 10.

7.4. COHERENT SYSTEMS AND COHERENCE TRUTH

An agreement has a coherence truth value, using this term as Bradley (1914) and later Rescher (1973) do. If the agreements in mind were concerned with propositions, then Rescher's formulation would provide all that is required. For example, an instance of T^* *is* designated by a proposition (*one* instance, however, is *one* result of executing some $Proc_A T^*$ in $Con_A T$ and some $Proc_B T^*$ in $Con_B T$). Knowing that A and B agree about circles does not necessarily permit any inference about the factual truth of whatever they agree (it may do, if their repertoires contain consensually agreed tests for circularity; for example some kind of templet), but there is no obviously plausible way in which A's and B's agreement over an instance of a myth can be assigned factual truth so far as *they* are concerned (nor any way at all in which A's and B's perfectly legitimate agreement over a factual falsehood can be factually true). Logical coherence, in other words does not *exclude* factual truth or veridicality, but it does require that whatever is agreed fits into the conceptual structures of A and of B, one or both of which may and usually do, evolve in the process.

Now, CT certainly models propositional coherence truth as the *result* of executing certain procedures in a coherent fashion. But, in order to do so, CT must extend the notion of propositional coherence into the procedural domain. Figures 7 and 8 represent, in ordinary language a series of questions and answers which meet with approval (not with some absolute correctness). Equisignificantly (for at this procedural level a question is a particular kind of command) the picture represents commands that request explanations from A to B, commands from B, addressed to A, also requesting explanations. These commands are obeyed (or not), by A and by B. So far as A and B are concerned, it is important to insist upon *obedience* [as against a metalinguistic statement (Aqvist, 1971; Belnap, 1969; Harrah, 1973; Rescher, 1973) of (say) termination].

There is an immediate formal difficulty, voiced by Von Wright (1963) over the truth status of an activity like answering and obeying or asking, and giving; there is the matter of process truth anyhow (for a process is coherently executed, it cannot just be glossed as an event). Further, there is another formal difficulty over the truth status of address and addressee (A asks B to do something, and something may be done, by B, or by both of them); at least, a many sorted action logic is needed to formalize this situation, one candidate is due to Nowakowska (1975, 1979).

So far as CT is concerned, these formal difficulties are not obtrusive in an A, B, conversation, provided that no absolute standard of correctness is required; all the necessary sanctions are satisfied, and all the necessary permissions are given by token of coherent execution. From the stance of an external observer of the A, B, conversation the position is, as will be noted in section 7.7, interestingly different.

7.5. THE DEFINITION OF A TOPIC

$Con_A T$, $Con_B T$ and T_A, T_B are personal connotations, or subjective intensions, of which the shared part is $Con_A T^*$, $Con_B T^*$, together with T^*_A, T^*_B, the common description T^*.

How does the shared subjective intension of circle (T^*) become the philosopher's "concept", the meaning of "circle" in language L?

According to CT the philosopher's concept arises by iterated, coherent execution, of the organizational closure of an L conversation, in which an arbitrary number of L users take part. Certainly, this definition has the properties that are required of the meaning of T*, at a given age, in one subculture or another. Presumably, the extrapolation to meaning in general, the meaning of T (rather than T*), is just as legitimate-or-not as the extrapolation of agreement over an understanding. It designates the organizational closure of an indefinitely iterated execution of some *Con* T (unqualified, or qualified by a civilization, only), just as stable concepts are obtained by extrapolating to a limit the *Procs* of which they are composed (recall that, order apart, *DB* and *PB* operations are also *Procs* and, section 5.4, of type *Con*).

In order to see the strength and realism of this criterion, notice that many L expressions of an interrogative or imperative and of an answering or explanatory kind have been uttered, perhaps recorded in books or by other means. Insofar as understanding over an agreement is accompanied by the construction of working models (as in Fig. 8), these models, forming collections of different, externally compiled, L *Progs*, are also part of the cultural environment. CT maintains that this picture of things, which can be expanded without difficulty to accommodate the architectural and technical heritage, the prevalent theories, as well as the body of L expressions, is as full an account of the meaning of T as any other. This totality is the epistemology of CT.

7.6. FORMAL AND OTHER THAN FORMAL (ANALOGICAL) TOPICS

An analogy relation consists in a distinction between universes of discourse or process interpretation (without other qualification, as *independence* section 4.4) together with a similarity between processes in the distinct universes (without other qualification, *isomorphism*). (Usually, distinctions *are* qualified by acts of predication and isomorphism *is* qualified, by a specific common feature.)

So far, the discussion has mostly been exemplified by other-than-analogical topics, like "circle", or a "myth" or "plane surface", or "cylinder". These are known as formal topics, in contrast to analogical topics (the rest), since A and B are not required to adopt any ontological commitment at all; they can opt for whatever axiom schemes and abstractions they like. They can discuss circles in terms of balloons, or cylinders, or real or imaginary compasses or as the locus of all points, equidistant from a given point on the plane; the fact being that no features of balloons or compasses or whatever *needs* to (though it *may*) figure in a conversation about circles (or any formal T).

In section 8, it is argued that the meaning in general of an agreement over the understanding of an analogical topic shares the properties just outlined in the case of formal topics, notably, that L conversations about analogical topics are also organizationally closed if agreement over an understanding is achieved. There are some important and intriguing differences between analogical and other than analogical modes of agreement, very large differences, but these do not demolish the topic-hood of analogies that are understood.

7.7. THE STATUS OF AN EXTERNAL OBSERVER OF L DIALOGUE

The original statement of CT gave precedence to an external observer, who is anxious to make sharp valued observations of an L conversation between participants A and B. The matter of observation is now approached from the opposite direction, to secure, on rather firmer ground, the original postulates.

It has been argued that the organizational closure of agreement over an understanding is an A, B, process-coherence which models a procedural extension of propositional coherence and may be designated procedural coherence. A and B are in agreement

insofar as they have licence, as participants, to assign (procedure) coherence truth to whatever it is they agree.

Consider an external observer who can comprehend L (the conversational language), but who communicates with other observers, and describes experiments to do with cognition, etc., in a reserved, usually scientific, metalanguage, L*.

Sharp valued observations, expressed in L*, are to have *factual* truth values.

In the case of formal topics T, these statements are of the kind

"It is factually true that A agrees with B over an understanding of T".

(There is a strict equivalence between such factual L* assertions and the termination statements of commands; in contrast, agreements, in L, are like obedience and disobedience.)

It is useful to rephrase the matter, as follows. L statements of agreement in a conversation are strictly *subjective* statements referring to A and B, the subjects. Agreements are surely quantifiable (in an equipment such as CASTE (Pask, Scott & Kallikourdis, 1973*a*; Pask, 1975*a*), or INTUITION (Pask, 1976*a*)); subjective statements *are* quantified and the CT proposal is that they *may* be quantified to an arbitrary accuracy, with limits set only by the indeterminancy of section 3.8. But the quantities used to characterize agreement remain subjective, for all that.

In contrast, an external observer's statement in L* has factual truth value, and is an *objective* statement which necessarily refers to an *it* (object) which is the *conversation*; not the participants.

So, by token of equipment like CASTE or INTUITION (or the space allegory noted in section 3.3), an external observer can specify, in L*, an apparatus capable of detecting the explanations, demonstrations, modelling, etc. that lead up to the organizational closure of a conversation and culminate in all of the conditions for agreement set out in section 7.3. The assertion that procedural coherence, or agreement has been reached (that "A and B agreed over an understanding of T"), is a purely objective statement about one object (or a collection of objects) called conversations, the *it*(s) under scrutiny.

Moreover, factually true objective statements in L* admit deterministic predictions about the progress of a conversation. For example, if the events symbolized in Fig. 9 are observed, then it is deterministically predictable that the stable concepts (Con_AT*, Con_BT*) depicted in Fig. 10 will form part of the subsequent conversation and these stable concepts, being permanent in that conversation, are also retrievable.

Certainly, the converse hypothesis is more difficult, for the mental organization of Fig. 10 may come about due to unobserved processes. Figure 9 is not the only path to understanding. Hence, CT predictions are conditional, and of the form "If stable concepts, Con_AR, (Con_BR), do not exist in A(B), and if an observation of organizational closure is made, then this closure, a stable concept, will be present in A(B)", and the most dramatic results come from studies where stable concepts are built up, *de novo*. But with this caveat, the CT prediction of stability is *very* strong.

Now what *kind* of L* statements are factually true; what kind of L* statements can be made about conversations? Here, there is a peculiarity. Strictly, these factually true statements are not propositional. They are L* metaphors designating analogy relations. Like any other analogy (section 7.6), these analogies depend upon and require the assertion of, a difference and of a similarity between A and B, the participants.

For who, after all, distinguished A and B, the conversational participants? Well, the external observer or his measuring equipment did. Further, the statement "A and B agree" only makes sense if A is somehow distinct from B and a myriad kinds of distinction could be employed with complete legitimacy. For example, A and B can be distinguished as biological organisms, in which case, they have fixed spatial locations; or as roles, like "teacher" and "learner", or as conceptual organizations. Neither roles nor conceptual organizations have, or can have (in conversation), fixed spatial locations. Some "Teacher processes" are necessarily executed in the "Learner's brain", and vice versa, if the tutorial transactions are successful and lead to learning. This much is immanent in the criterion "organizational closure of a conversation" between "organizationally closed (autonomous) participants", and this much is uncovered by a proper reading of Figs 9 and 10.

The similarity in the analogical form

"A agrees with B to an understanding of T"

is the production system of Fig. 10. The observer's distinction of A, B, will be written $Dist_{OB}(A, B)$.

7.8. RELATIVISTIC AND REFLECTIVE STATUS OF CT

The property of CT that L* analogies only are factually true or false (whereas L statements have the coherence truth value of an agreement), is not unique; for example, similar comments are certainly applicable to a fully fledged decision theory of complex individual or team decisions, almost certainly, to either jurimetrics or government, and, probably, to economics.

For one reason or another (perhaps it is the weight of conventional wisdom) there is a general reluctance to follow through the consequences of this property in any field, and CT is the first, moderately precise, attempt to do so. There is a great deal of rather general discussion of perspectives, self images, and the like which may furnish useful guidelines for practitioners in psychiatry, market research, etc., but with the exception of Bateson (1973) and Laing (1961), the grain of the discussion renders criticism, on theoretical grounds, irrelevant. The resurgence of interest in "personal construct theory" (Bannister, 1970; Bannister & Mair, 1968), does, also, open the door to debate and although the first steps in this direction have been hampered by the purely adjectival interpretation of constructs (which comes, in large measure, as a by-product of the "Grid" technique), the picture is changing quite rapidly (for example, Shaw & Thomas, 1977; Boxer, 1979), and there are some serious attempts to place personal constructs on a sound theoretical framework in accord with Kelly's original work (Shaw & Gains, 1979; Boxer, 1979).

The "peculiar" property of sharp valued L* observation in CT has several consequences. Of immediate interest it renders CT an explicitly *relativistic* and *reflective* theory of conceptual operations.

(a) The *relativistic* character (Helson, 1964; Cohen, 1974, Jacques, 1956) is shared, though seldom made explicit, by most psychological theories.

In CT, observations are seen as relative to a reference frame of related topics at which the participants are able to point, to reach agreement about and to agree to understand, the "entailment meshes" of section 2. The topics are L-tokens or L-inscriptions of agreements, of shared stable concepts. They represent occasions upon which these or other autonomous participants, take part in a conversation which, by organizational closure, has autonomy in its own right without the participants loosing theirs. So, in general, the "entailment meshes" of CT evolve and, with them, the frame of reference relative to which observations are made.

(b) The reflective aspect is most readily introduced as follows. Suppose the participants cannot only agree about formal topics (a process that an external observer notes as the factual truth of an L* analogy), but also agree to an understanding of L-analogical topics.

That they do so, has already been mooted.

Suppose, also, that agreement over the understanding of an L-analogy is observable, and is recorded as the factual truths of an L* analogy between L* analogies. Of course, this *could* lead to an infinite regress, but it *need* not do so, for the external observer must notice, if ever he observes such an event, that participants, A and B, are performing the same kind of action (L-analogy construction and forming agreements to understand L-analogies) that he is performing and due to which performance he is authorized to adopt the numinous stance of external observer.

Stated conversely, any participant has the power to opt into the role of external observer and the external observer may act, in reverse, as participant observer (like an interviewer, or a psychiatrist), or simply as a participant, with no especially reserved position.

8. Essential bifurcations, and L analogical topics

If, as proposed, A and B can be observed to agree over the understanding of an analogy, one or both of them must *have* an analogy, at the outset. This possibility was noted in section 4.3, with the "internal" agreement between distinct *perspectives*, both belonging to one participant, (say perspectives AX and AY, belonging to A, where AX and AY are potentially independent L-processors, that coexist in the computing medium, occupied by A). If procedures, (in general, if stable concepts), are executed independently and incoherently, and if AX, AY, come into (at least, local) coherence (synchronicity, dependency) because of an AX to AY information transfer, then, from section 4.3, there is a *weak* internal agreement, and a weak L-analogy. The AX, AY agreement, (hence, the L-analogy), becomes *strong*, if there is an agreement over an understanding. In this case, the AX, AY agreement is a stable analogical concept; for example, an internal agreement over an understanding of T_{AX} and T_{AY} may be a stable analogical concept T^*_A. The same notation is applicable to any other participant, B: to give BX, BY, as processors accommodating concepts for T_{BX} and T_{BY} and a stable analogical concept T^*_B.

The concepts for T^*_A and T^*_B($Con_A T^*$, $Con_B T^*$) are executed in some processors $\mathcal{U}$A, $\mathcal{U}$B, that contain the "internal conversations" between two perspectives AX, AY, of A; and the two perspectives, BX, BY, of B. But $A\mathcal{U} \neq AX \neq AY$ and $B\mathcal{U} \neq BX \neq BY$. The distinction of AX, and AY, or BX and BY must also be maintained by computations performed in $A\mathcal{U}$ or $B\mathcal{U}$.

It will be argued that the information transfer, required to obtain coherence between the processes going on in AX and in AY, respectively, (across $Dist_A(X, Y)$), or between those going on in BX and BY, (across $Dist_B(X, Y)$), respectively *is*, in fact, A's stable analogical concept. $Con_A T^*$ such that $Ex\ (Con_A T^*) \Rightarrow T^*_A$, or (in the case of B), B's stable analogical concept $Con_B T^*$, such that $Ex\ (Con_B T^*) \Rightarrow T^*_B$. $Con_A T^*$ and $Con_B T^*$

couple AX, AY, or BX, BY, just as an external agreement, in an L conversation, couples A and B into coherent activity, *across* a distinction $Dist_{OB}$(A, B).

The process may, however, be iterated. The participants may agree about an understanding of their stable analogical concepts, that is, about T*, and a common concept of T*, namely *Con* T*, such that *Ex* (*Con* T*)$\Rightarrow$T*. The reflective character of CT will be exhibited by showing that $Dist_{OB}$(A, B) may be substituted by distinctions $Dist_A$(A, B) and $Dist_B$(A, B); further, it will be argued that

(a) Distinctions can be *constructed*, as well as *assumed* to exist (so that agreements can take place *across* them).

(b) The act of agreement may lead to conditions under which distinction *must* be constructed, in order to maintain stability.

8.1. DISTINCTIONS

There is a general tendency to overlook the distinctions, $Dist_A$ (X, Y) and $Dist_B$ (X, Y), which are essential to analogy. Without them, the interlocked processes and the information transfer are pointless, or even meaningless. This is why the potentially powerful notion of analogy is regarded askance, in much of the literature; for analogies are usually rendered as similitudes, and, as such, have little inferential strength.

By way of contrast, it is maintained that an agreement over understanding an analogy is *just* as *strong* as an agreement over understanding an other-than analogical (or formal) concept; that a *stable* analogical concept, is *just* as *strong*, in cognition or otherwise, as any other stable concept. There is, however, a difference between a formal and an analogical stable concept.

Formal concepts may, and, when iterated, often do, approach a limiting condition, in the L computing medium, where no (Petri type) information transfers are implicated, either in the maintenance or use of the stable concept (as, for example, the execution of a well learned skill, like driving, most memorizing, some mental addition).

Analogical concepts also approach limiting conditions in the L computing medium; however, information transfer *is* implicated, (even *in* this condition) whenever the stable concept is maintained, *or* used. (Because, in fact, a distinction must be constructed, if the concept is executed.)

8.2. SINGULARITY AND BIFURCATIONS: AGREEMENTS THAT LOSE THE DISTINCTION NEEDED FOR STABILITY

Consider the production scheme in Fig. 10, (which has a distributive form), an L-agreement over an understanding of T.

Consider, also, the productions in Figs 2 or 3, (which have a collective form), distinct stable formal concepts for T, entertained by A and B.

The distributive form of Fig. 10 is the normal outcome of an A, B, agreement over an understanding, of T. Now, suppose there is a superficially innocent modification, that A derives Con_AT from concepts for P_A and K_A, that B derives Con_BT from concepts for R_B and K_B. The participants (A, B) may, thus tend to an "agreement" characterized, as follows:

$$T_A \supseteq T^*_A \Leftrightarrow T^* \Leftrightarrow T^*_B \subseteq T_B,$$

$$K_A \supseteq K^*_A \Leftrightarrow K^* \Leftrightarrow K^*_B \subseteq K_B,$$

together with expressions, for P_A, and for R_B:

$$P_A \supseteq P^*_A \Leftrightarrow P^* \Leftrightarrow P^*_B,$$

$$R^*_A \Leftrightarrow R^* \Leftrightarrow R^*_B \subseteq R_B,$$

as given in section 7.

The modification produces a singularity (or a bifurcation surface), in the description of an organizationally closed system, and it induces an essential bifurcation in the process that is described. To demonstrate the point, it is only necessary to examine the productions which would characterize an "agreement" about an understanding, which is, as required, an organizational closure. These productions are

$$DB\ (K^*, T^*) \Rightarrow P^*; \qquad DB\ (K^*, T^*) \Rightarrow R^*.$$

But $P^* \neq R^*$, so that the *same* process is required to achieve *different* results, i.e. different descriptions or behaviours. The absurdity is even more cogently pinpointed on noting that, for $P^* \neq R^*$,

$$PB\ (Con\ K^*, Con\ T^*, P^*) = PB\ (Con\ K^*, (Con\ T^*, R^*).$$

There is, in other words, *no* agreement. The required stable concept does not exist *unless* A = B, in which case "agreement" is meaningless.

8.3. "SOLUTIONS" TO THE "BIFURCATION PROBLEM"

The most popular expedients for "solving the problem" are (1) temporal independence, and (2) personal independence.

(1) *Temporal Independence* (discrete intervals are *a priori* independent), admits a discrete oscillator, so that one description, or behaviour, is agreed on some occasions and the other (in general, the others) upon different occasions. Th^ possibility is real enough. It is manifest, for example, in "switching illusions", such as the perception of a Necker Cube. The objection to temporal independence is simply that it is a special, rather than a general, case. If used out of place, it leads to the counterfactual conclusion that people (or other sentient beings), live in what Gregory (1970) christened Bishop Berkley's "jerky world".

(2) *Personal Independence* [Lewin's "Genidentity" discussed by Richenbach (1947) individuals persist, but are *a priori* independent] consists in subscripting the stable concepts, and retaining the subscript with distinct values (one of A or B), even if the concept *is* shared. Now, given that A and B are *always* distinguished, productions such as

$$DB_A\ (K^*_A, T^*_A) \Rightarrow P^*_A; \qquad DB_B\ (K^*_B, T^*_B) \Rightarrow R^*_B$$

are valid, depending, entirely, upon the A, B, distinction. In the limit, quite possibly

$$K_A \supseteq K^*_A \Leftrightarrow K^*_B \subseteq K_B,$$

so that A's description and B's description, being isomorphic, are only distinguished by the names, A, B.

Quite possibly, when there is but one distinction, this makes good sense. As a conjecture, the self identity learned by a neonate relies upon that trick. But, if extended over *all* descriptions (or all concepts), personal independence leads to a curious kind of solipsism, which disallows "concepts", in the philosopher's sense, leaving, at the most, a universalized "subjective intension" like "your concept of a horse", or "my concept of a horse", and which, without special knowledge of "you" and "I", may never be shared.

8.4. THE ORIGIN OF DISTINCT DESCRIPTIONS

In the definition of a stable concept, during section 5 (and the definition of a description in section 4.1), it was deliberately, although naturally, ordained, that operators, *DB*, can produce descriptions that deviate from an already existing description. There are some (a), that are, and some (b), that are not, part of the organizational closure called a "stable concept". In particular, either descriptions of DB_A, PB_A are amongst the products of a stable concept or DB_A, PB_A (type *Con*) are products of some other stable A-concept and, as such, simply *exist*.

Let the already existing description be K and the deviant description be $K' \neq K$.

In case (a), the deviant descriptions, K′, forms part of the Gaines–Zadeh-type Fuzzy result of executing a cluster of closed and coherent (or near-coherent) procedures, i.e. K, K′, is an enlargement of the stable concept's description. In case (b), the *PB* operations do not, or cannot, form procedures, with the closure property, that also produce K, K′ upon execution. In case (b), let $M = K' \neq K$, as a more convenient notation.

There is *nothing* whatever to preclude the construction of a *distinct* concept in which $K' = M$ forms part of an organizationally closed system, and such a displacement does permit an otherwise prohibited agreement between A and B.

So, whereas an arrangement described by

$$T_A\,(P_A, K_A), \quad \text{and by} \quad T_B\,(R_B, K_B),$$

(as a shorthand for closed, collective productions like Figs 2 and 3) does *not* yield a stable distributive form (section 8.2) the *displaced* arrangement, described by

$$T_A\,(P_A, M_A) \quad \text{and by} \quad T_B\,(R_B, K_B),$$

does yield a stable agreement, the distributed form

$$T^*((P^*, M^*)(R^*, K^*)),$$

(as a shorthand for closed, distributive, productions like Fig. 10).

This is, perhaps, the simplest case of resolving a potential bifurcation in an agreement over T; by means of a displacement, $K_A \Rightarrow K_A, K'_A; K'_A = M_A$. As before, the necessary *DB* operations, for A and for B, are

$$DB_A(T_A, P_A) \Rightarrow M_A, \qquad DB_B(T_B, R_B) \Rightarrow K_B,$$

$$DB_A(T_A, M_A) \Rightarrow P_A, \qquad DB_B(T_B, K_B) \Rightarrow R_B,$$

$$DB_A(P_A, M_A) \Rightarrow T_A, \qquad DB_A(R_A, K_A) \Rightarrow T_A,$$

(together with *PB* productions, acting upon Con_A, and upon Con_B, like)

$$PB_A(Con_A T, Con_A P, M_A) \Rightarrow Proc_A M \text{ in } Con_A M,$$

$$PB_A(Con_A T, Con_A M, P_A) \Rightarrow Proc_A P \text{ in } Con_A P,$$

or like

$$PB_B(Con_B T, Con_B R, K_B) \Rightarrow Proc_B K \text{ in } Con_B K,$$

$$PB_B(Con_B T, Con_B K, R_B) \Rightarrow Proc_B P \text{ in } Con_B P.$$

Also, for the shared description

$$DB_A(T^*, P^*) \Rightarrow M^*, \qquad DB_B(T^*, P^*) \Rightarrow M^*,$$

$$DB_A(T^*, M^*) \Rightarrow P^*, \qquad DB_A(T^*, M^*) \Rightarrow P^*,$$

$$DB_A(P^*, M^*) \Rightarrow T^*, \qquad DB_B(P^*, M^*) \Rightarrow T^*,$$

$$DB_A(T^*, R^*) \Rightarrow K^*, \qquad DB_B(T^*, R^*) \Rightarrow K^*,$$

$$DB_A(T^*, K^*) \Rightarrow R^*, \qquad DB_B(T^*, K^*) \Rightarrow R^*,$$

$$DB_A(R^*, K^*) \Rightarrow T^*, \qquad DB_B(R^*, K^*) \Rightarrow T^*,$$

(together with *PB* productions, acting upon Con^*_A, or Con^*_B, like)

$$PB_A(Con_A T^*, Con_A P^*, M^* \Rightarrow Proc_A M^* \quad \text{in} \quad Con_A M^* \quad \text{or in} \quad Con_A M,$$

$$PB_A(Con_A T^*, Con_A R^*, K^*) \Rightarrow Proc_A K^* \quad \text{in} \quad Con_A K^*,$$

or like

$$PB_B(Con_B T^*, Con_B R^*, K^*) \Rightarrow Proc_B K^* \quad \text{in} \quad Con_B K^* \quad \text{or in} \quad Con_B K,$$

$$PB_B(Con_B T^*, Con_B P^*, M^*) \Rightarrow Proc_B M^* \quad \text{in} \quad Con_B M^*,$$

exhibited for *all* terms, but notice that the productions transferred from A to B, or B to A, are incomplete; for example, that $Con_A K^*$ is *not* in $Con_A K$; that $Con_B M^*$ is *not* in $Con_B M$, for $Con_A K$ and $Con_B M$ do not exist.

8.5. INTERNAL RESOLUTION BY ONE PARTICIPANT

In the specification of an L computing medium (sections 3.4–3.8), it was deliberately, although naturally ordained that it is always possible to dissect the L computing medium into *a priori* independent laminae, which (a) may be rendered synchronous, coupled or coherent or (b) may remain distinct. For case (a) the organizational closure of a stable concept can be achieved, without adding further distinctions to the system. For case (b), a distinction between autonomous, closed, units, must be *computed by* the system, *in order* to achieve an overall closure of the system.

For (a) in a displacement $K_A \Rightarrow K_A, K'_A$; $K'_A = M_A$ is eliminated (from the simple structure under consideration). The laminae of the L computer medium are only deployed as the concurrent processor needed to accommodate *any* stable concept, even a *formal* concept, because the constituent L Processors are not differently named, say as X and Y. For (b), a distinct stable concept could emerge from a bifurcation resolved by an internal agreement if a distinction is computed (it is a matter of indifference whether it is called a distinction between L processors, or between stable concepts). As usual, a recursive type of argument is needed.

Suppose $T_A \Rightarrow T_A, T'_A$

$$\text{Let } T_A = T_{AX} \text{ if } T'_A = T_{AY} \text{ (Displacement).} \qquad (Pr.\ 1)$$

X and Y (or AX, AY), are *not*, as yet, specified. However, introduce a production

$$DB_A(T_{AX}, T_{AY}, T^*_A) \Rightarrow Dist_A\,(X, Y) \text{ (Predication).} \qquad (Pr.\ 2)$$

To yield a predicate, $Dist_A(X, Y)$ with independent (though not, as yet, distinguished), values of X and Y appearing in

$$DB_A(T_{AX}, T_{AY}: Dist_A(X, Y)) \Rightarrow T_A^*,$$
$$DB_A(T_{AX}, T_A^*, Dist_A(X, Y)) \Rightarrow T_{AY},$$
$$DB_A(T_{AY}, T_A^*, Dist_A(X, Y)) \Rightarrow T_{AX}. \qquad (Pr.\ 3)$$

Hence there *is* (by prior postulate) a processor, $A\mathcal{U}$, to execute the DB_A operations. These productions make sense provided that $A\mathcal{U}$ also has the *PB* operations.

$$PB_A(Con_A T_{AX}, Con_A T_{AY}, T_A^*) \Rightarrow Proc_A T^* \quad \text{in} \quad Con_A T^*,$$

such that

$$Ex\,(Con_A T^*) \Rightarrow T_A^*,$$
$$PB_A(Con_A T^*;\ Con_A T_{AX}, T_{AY}) \Rightarrow Proc_A T_{AY} \quad \text{in} \quad Con_A T_{AY},$$
$$PB_A(Con_A T^*, Con_A T_{AY}, T_{AX}) \Rightarrow Proc_A T_{AX} \quad \text{in} \quad Con_A T_{AX}, \qquad (Pr.\ 4)$$

executed by $A\mathcal{U}$ with

$$Ex\,(Con_A T_{AX}) \Rightarrow T_{AX} \text{ by AX, and } Ex\,(Con_A T_{AY}) \Rightarrow T_{AY}, \text{ by AY.} \qquad (Pr.\ 5)$$

There exist, before the displacement of *Pr.* 1 certain supporting productions all of which are under execution in *A* (and, at *that* moment, before *Pr.* 1, *A* is equivalent to AX, say).

These are:

$$DB_A(P_A, K_A) \Rightarrow T_A,$$
$$DB_A(T_A, P_A) \Rightarrow K_A,$$
$$DB_A(T_A, K_A) \Rightarrow P_A,$$
$$PB_A(Con_A Q, Con_A K, T_A) \Rightarrow Proc_A T \quad \text{in} \quad Con_A T,$$
$$PB_A(Con_A T, Con_A P, K_A) \Rightarrow Proc_A K \quad \text{in} \quad Con_A K,$$
$$PB_A(Con_A T, Con_A K, P_A) \Rightarrow Proc_A P \quad \text{in} \quad Con_A P. \qquad (Pr.\ 6)$$

It would have been just as legitimate to have written (but, as an *alternative*) the productions

$$DB_A(Q_A, K_A) \Rightarrow T_A,$$
$$DB_A(T_A, Q_A) \Rightarrow K_A,$$
$$DB_A(T_A, K_A) \Rightarrow Q_A,$$
$$PB_A(Con_A Q, Con_A K, T_A) \Rightarrow Proc_A T \quad \text{in} \quad Con_A T,$$
$$PB_A(Con_A T, Con_A Q, K_A) \Rightarrow Proc_A K \quad \text{in} \quad Con_A K,$$
$$PB_A(Con_A T, Con_A K, Q_A) \Rightarrow Proc_A Q \quad \text{in} \quad Con_A Q. \qquad (Pr.\ 7)$$

Notably, the joint inscription of *Pr.* 6 and *Pr.* 7 as co-existing production schemes that are concurrently executed in a computing medium (*not* as *alternative* schemes) leads to

a bifurcation in the system dynamics. This event is non-trivial; for example, if the names T, P, Q, K, . . . are regarded as names of variables (or, in any other sense, as occupants of the computing medium) the bifurcation not only ambiguates the *values* of these variables, but the *character* of the variables, and the existence of the variables.

The interpretative argument is as follows:

If A, as characterized in CT, is said to adopt two or more points of view of perspectives, simultaneously, and to juxtapose them as concepts of T_A, then this event is uniquely represented by the co-existence of production schemes (such as) *Pr.* 6 and *Pr.* 7. No other *type* of interpretation is possible (obviously, A may have differently structured stable concepts, may attend to different stable concepts and so on). If this event occurs, it is always liable to induce a bifurcation; and in this (or many other cases) it *does* so.

Conversely, the co-existence and bifurcation of L processes that belong to (or are named after) A, means, uniquely, that A *does* simultaneously adopt *and* juxtapose two or more points of view, or perspectives.

The bifurcation, for initial perspectives *Pr.* 6 and *Pr.* 7 leads to the displacement of *Pr.* 1 and the predication of *Pr.* 2.

But if *Pr.* 3, *Pr.* 4 and *Pr.* 5, then *Pr.* 6 and *Pr.* 7 *may* co-exist as an organizationally closed (stable) concept given the following induced substitutions in *Pr.* 6 *and Pr.* 7 (the various substituents being specified in *Pr.* 3, *Pr.* 4 or *Pr.* 5).

For each occurrence of T_A in *Pr.* 6, substitute T_{AX},
For each occurrence of $Proc_A T$ in *Pr.* 6, substitute $Proc_A T_{AX}$,
For each occurrence of $Con_A T$ in *Pr.* 6, substitute $Con_A T_{AX}$.

Similarly

For each occurrence of T_A in *Pr.* 7, substitute T_{AY},
For each occurrence of $Proc_A T$ in *Pr.* 7, substitute $Proc_A T_{AY}$,
For each occurrence of $Con_A T$ in *Pr.* 7, substitute $Con_A T_{AY}$. (*Pr.* 8)

The resulting scheme is an "internal" L conversation between A's perspectives, AX, AY (or, more accurately $Ex\,(Con_A T_{AX}) \Rightarrow T_{AX}$ by AX, and $Ex\,(Con_A T_{AY}) \Rightarrow T_{AY}$ by AY).

Pr. 1, *Pr.* 2 and *Pr.* 8 *are* the juxtaposition.

Pr. 3, *Pr.* 4, *Pr.* 5, *Pr.* 6 and *Pr.* 7 resolve the bifurcation. If resolution is obtained, then a stable analogical concept is constructed and this "internal" (i.e. between perspectives of A) agreement over an understanding of T_{AX}, T_{AY}, *is* the execution of a stable analogical concept, $Ex\,(Con_A T^*) \Rightarrow T_A$, by A.

The minimal assumption, tenable unless it is qualified by specialization, is that T_{AX} and T_{AY} are *isomorphically* related by T_A^* (the content of the similarity in the analogy); that $Ex\,(Con_A T_{AX})$ in AX and $Ex\,(Con_A T_{AY})$ in AY are held *independent* by the analogical distinction, $Dist_A(X, Y)$ apart from the coupling established by $Ex\,(Con_A T_A^*)$, in $A\mathcal{U}$, the analogical universe. This is pictured by the symbolism in Fig. 11.

8.6. HYBRIDS

Suppose that A had juxtaposed perspectives $Ex\,(Con_A K_{AX})$ and $Ex\,(Con_A K_{AY})$, instead of $Ex\,(Con_A T_{AX})$ and $Ex\,(Con_A T_{AY})$. This is certainly permitted, by the symmetry of the arrangement, and any organizationally closed system will have at least

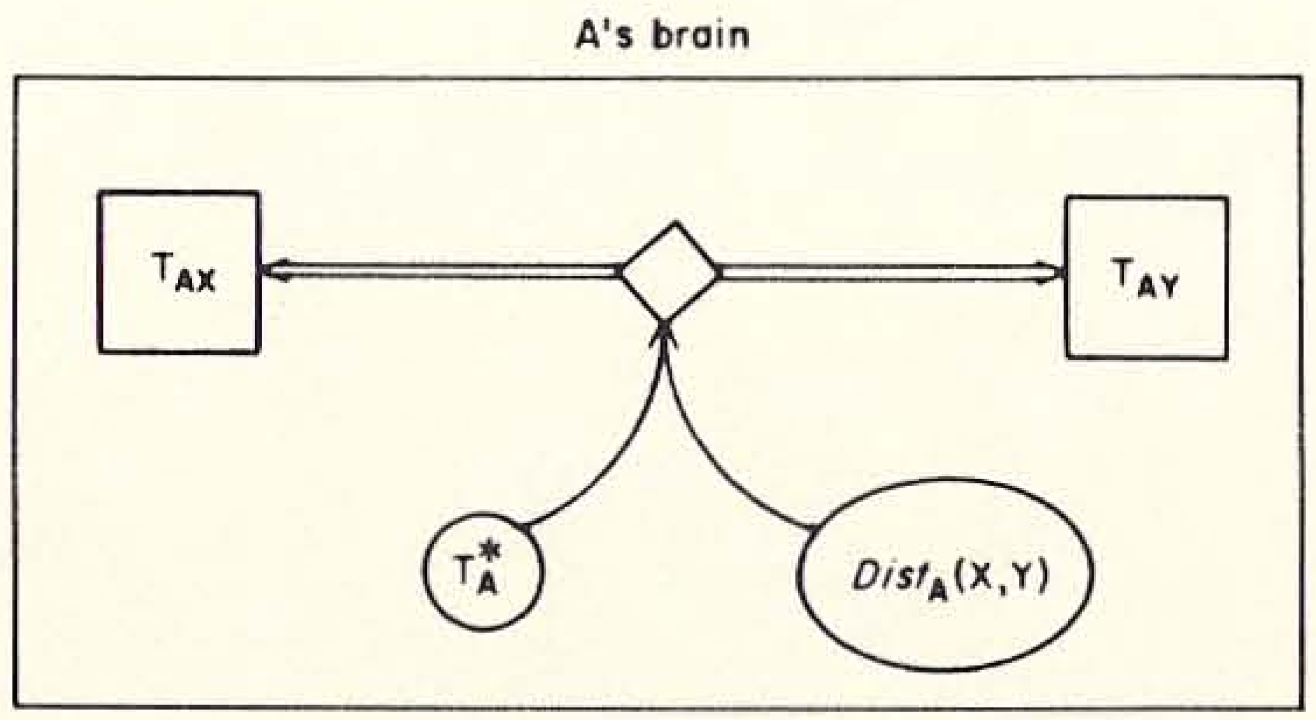


FIG. 11.

as many symmetries. Initially, *Pr.* 1 is rewritten to read

$$K_A \Rightarrow K_A, K'_A$$

rather than

$$T_A \Rightarrow T_A, T'_A,$$

and following the production schemes up to *Pr.* 8, the stable analogical concept is written, in the shorthand of Fig. 11, as $Ex\ (Con_A K^*) \Rightarrow K_A^*$ with distinction $Dist_A(X, Y)$ and similarity K_A^*. In this structure $Con_A T^*$ and $Con_A K^*$ are hybrids

$$Ex\ (Con_A T^*) \rightleftarrows Ex\ (Con_A K^*)$$

and

$$T_A^* \rightleftarrows K_A^*.$$

These hybrid forms may co-exist

$$Ex\ (Con_A T^*) \quad \text{and} \quad Ex\ (Con_A K^*)$$

$$T_A^* \quad \text{and} \quad K_A^*$$

which, barring structural elaboration, is the most complete organizational closure and, by interpretation, the most stable analogical concept (their co-existence is equivalent to resonance, or co-operation, rather than hybridization).

8.7. AGREEMENTS TO UNDERSTANDING ANALOGICAL CONCEPTS

Suppose that A has constructed the stable analogical concept, $Con_A T^*$ of T_A^* and that B, the other participant in an L conversation, has constructed a stable analogical concept, $Con_B T^*$ of T_B^* that is executed in an L processor $B\mathcal{U}$, between $Ex\ (Con_B T_{BX}) \Rightarrow T_{BX}$ and $Ex\ (Con_B T_{BY}) \Rightarrow T_{BY}$. In conformity with Fig. 9 and Fig. 10 suppose that B's stable concept T_{BX} is derived from concepts for R_B and S_B. B's stable concept for T_{BX} from (say) concepts for L_B and N_B. This possibility is shown in Fig. 12, and there is no

difficulty in constructing a production system, which is a replica of Fig. 10, to represent an agreement over an understanding of T_A^* and T_B^* by A and B; this agreement, T^* is shown in Fig. 12 for the case in which the participants are distinguished, through $Dist_{OB}(A, B)$ by an observer. Figures 9 and 10 as they stand, represent A, B, agreements over understandings of *formal* concepts, such as concepts for T_{AX}, T_{BX} and P_A, R_B, or Q_A, S_B.

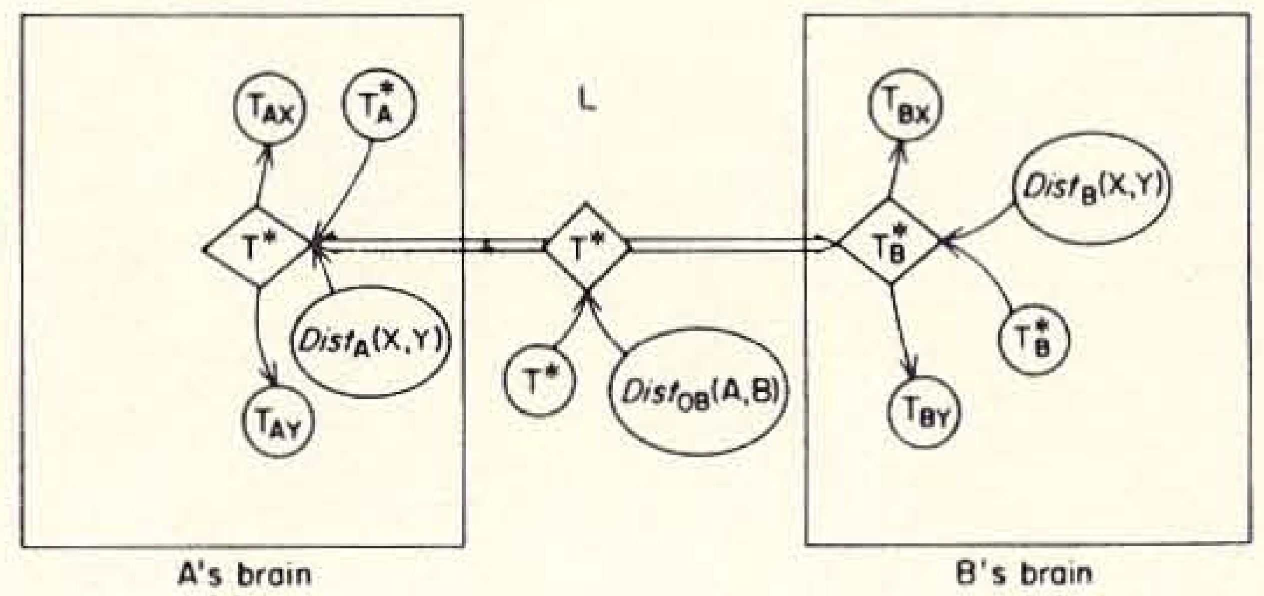


FIG. 12. Exteriorized agreement over the understanding of an analogy T^* between A's stable concept of an analogy T_A, and B's stable concept of an analogy T_B taking place in the conversational language L.

There is nothing in the argument to forbid more than two perspectives, or more than two participants. Apart from notational convenience, there is no reason to select two perspectives, or two participants, to begin with. The fact that $Dist_A(X, Y)$ is computed in $A\mathcal{U}$, that $Dist_B(X, Y)$ is computed in $B\mathcal{U}$, and that $Dist_A(A, B)$ and $Dist_B(A, B)$ are computed in an interpreted conversational language, L, suggests the property which Varela (in a research note on Dialetic modes of debate) captures, as a "trinity operator". Gaines (1978) makes a similar point, using a different idiom, in a recent essay upon "Decision".

Finally, when participants agree to understand a stable analogical concept, there is no reason, apart from notational convenience, why they should agree to understand the "*same* analogy". In particular, they will not, in fact, do so, if a stable concept of this analogy is necessarily *distributed* between them (if there is the "necessary co-operation" between the participants, noted in section 4.4).

8.8. REFLECTIVITY AND LANGUAGE USAGE

Both A and/or B *can* entertain perspectives and juxtapose them to initiate an internal L conversation. That is the mechanism for constructing a stable analogical concept. In this case, however, they compute their own distinctions between perspectives (which act as the internal participants), as $Dist_A(X, Y)$ or $Dist_B(X, Y)$ in $A\mathcal{U}$ and in $B\mathcal{U}$. Is there any reason, if that is so, why A and B cannot make their *own* distinctions, $Dist_A(A, B)$, and $Dist_B(A, B)$ to replace $Dist_{OB}(A, B)$? The reply is affirmative. There is *no* reason why they should not distinguish themselves.

It would be counterfactual to hold otherwise, but it is worth examining what is needed in order that A and B *may* do so. Manifestly, they do, already, have the basis for computing a distinction (*Pr.* 2 and *Pr.* 3 of section 8.5) only, they need some independent processors in which to do so.

I maintain that an adequate conversational language provides this free processor; in other words, that language is used as such a thing. The laboratory interfaces, like THOUGHTSTICKER and the Decision System, provide very concrete, tangible, though slightly restricted exemplars in which L does have the required characteristics; of dynamism computing capability, and the rest. In a later paper, it is argued that one version of L, namely Lp, is, amongst other things, a peculiarly adapted computing medium which permits, encourages, aids and promotes just this kind of exteriorization of conceptual operations. L, and Lp in particular, is not *just* a communication medium but a dynamic system *modulated* by language users such as participants A and B in which they may, for example, build up $Con\,T^*$, such that $Ex\ (Con\,T^*) \Rightarrow T^*$(any of the *earlier* systems allowed A and B to exteriorize $Prog_A T^*$, $Prog_B T^*$ as *serially* interpreted *models*, for execution to yield T^*_A, T^*_B).

Slightly restricted systems like THOUGHTSTICKER are indisputably capable of doing their proper task. But I wish to extend the notion of language as a kinetic entity, and of natural language as a socio-cultural medium which is modulated by users, without too much restriction. This view is something of a departure from the current conventional wisdom of linguistics, and, quite possibly, it will prove contentious. It is, however, a very plausible view if natural language is construed with greater-than-usual generality, to include not only spoken language and written language, but graphical forms, the language proper to the subculture of people in transit (the sociology of driving, for example, is very real), the varied languages of architecture, art, drama, science and technology. The later paper is devoted to a justification and development of this view.

At this juncture it is apposite to comment that *if* a conversational language does satisfy the kinetic requirements needed for A and B to distinguish themselves, and agree over the analogies they construct, *then* CT, is, as claimed, a genuinely reflective theory.

8.9. VARIETIES OF STABLE CONCEPT IN L

"A stable concept is an organizationally closed system of productions."

This statement neither affirms nor denies the proposition, "the system is informationally open", organizational closure may, or may not, go along with information transfer.

It has been argued that the construction of any stable concept does involve information transfer. But, subsequently, there is a difference between a stable other-than-analogical concepts (a formal topic) and a stable analogical concept, as follows.

For Stable Formal Concepts, there *may be*, but *need not* be, information transfer. Left to mature, information is trapped inside the closure (the information transfer, is within the stable concept, between candidate procedures, that are rendered coherent with the existing cluster). Eventually, procedures in stable formal concepts tend to parallel execution; the constituent *Progs* are recompiled in the L computing medium to achieve this result, and subsequent use of the concept does not necessarily involve information transfer. In this automatic state, the conceptual system is organizationally closed, *and* informationally *closed* (no transfer).

Conversely, a stable analogical concept is a system of productions which is both organizationally closed *and* informationally *open*. At any point, use or execution of the concept implicates an information transfer (a non-trivial, even though internal, conversation between *perspectives*).

All stable concepts, if exchanged over an arbitrary population of participants, become, in the limit, topics in L (formal topics and analogical topics).

The topics of stable analogical concepts behave like formal topics, except that their informationally open quality is retained. Whenever such a topic is used or exchanged information *must* be supplied (over and above any information transfer due to an ordinary conversation) in order to stipulate the distinctions that are an integral, and essential, part of the topic.

The vestiges of this quality remain even in the most arid and lifeless images of what language *is*. It is *always* possible to substitute an *indefinite* number of distinguishing predicates that *will*, equally well, support the similarity of the analogical topic.

8.10. UNIFORMITY OF CONCEPTS, PERSPECTIVES AND PARTICIPANTS

Due to the recursive character of the definitions it is possible to demonstrate a uniform representation of stable concepts, perspectives, participants, and conversations. For this purpose introduce a connective "In Closure of", or "*Incl*", between concepts meaning that if $\alpha\ Incl\ \beta$, and α and β are part of a production scheme, like Fig. 2 or like Fig. 10. Thus, "In" of "In Con", is a restricted case of *Incl*, since $Proc_A T$ is a special case of $Con_A T$ as given in the account of stability (recapitulated from section 5.2):

$$Con_A T \triangleq Proc_A T \quad \text{or} \quad [Proc_A T] \quad \text{or} \quad \{\{Proc_A T\}, [Proc_A T]\}$$

$$Ex\ (Con_A T) \Rightarrow T_A, \quad Ex\ (Proc_A T) \Rightarrow T_A,$$

together with productions like Fig. 2 or like Fig. 10 (collective and distributive forms).

Notice that stable concepts, though initiated as collective forms, have built into their stability and closure mechanism the elements of a distributive form (insofar as novel procedures are produced and reproduced to obtain T by different methods). So, for example, in Fig. 2:

$$Con_A P\ Incl\ Con_A T\text{:}\ \ Con_A Q\ Incl\ Con_A T$$

$$Con_A T\ Incl\ Con_A P\text{:}\ \ Con_A T\ Incl\ Con_A Q$$

$$Con_A P\ Incl\ Con_A Q\text{:}\ \ Con_A Q\ Incl\ Con_A P.$$

A's perspective say from $Con_{AX} T_A$ of XA is constructed as the collection made up of all stable concepts in the closure of $Con_{AX} T$, where, if i is a variable, indexing concepts

$$Perspective\ (T_{AX}) \triangleq \text{All}\ Con_A i\ Incl\ Con_{AX} T$$

(in fact, those executed in AX).

If more than one perspective is involved, as in the construction of a stable analogical concept, there is a necessary information transfer, symbolized (if j and k are indices over perspectives), by *Inftr* Z, (j, k). *A fortiori* stable analogical concepts are all of this kind, for example, $Con_A T^*$, of T^*_A.

$$\textit{Stable analogical concept} \triangleq \langle \textit{Perspective}\ A_j,\ \textit{Perspective}\ A_k,\ \textit{Inftr}\ Z\ (j, k)\rangle$$

In general, for j in A and k in B:

$$\textit{Conversation over an understanding between A, B.} \triangleq \langle \textit{Perspective}\ A_j,\ \textit{Perspective}\ B_k,\ \textit{Inftr}\ L\ (j, k)\rangle.$$

In such a conversation a participant, relative to any one perspective, is the collection *of* all perspectives related to it by stable analogical concepts, and the information transfer *between* them.

The reflective character of CT, noted in section 7.8, is retrieved and refined, by a different path; participants are *expressed*, uniformly, by an (internal) conversation. But participants take part in an (external) conversation (*between* participants).

This type of definition scheme is canonical because it expresses the potentially-autonomous units and system-like entities of conversation theory (such as stable concepts, perspectives, participants and the rest) as special cases *of* L conversations. That being so, the units, systems, etc. are represented in terms of the *kind* of entity (namely "L conversations") that were originally stated to *be* "objects of observation".

Several advantages follow from adopting this type of definition, rather than partitioning the territory in some other way, for example, by isolating A's brain, and B's brain, or by delineating salient properties of their behaviour. One immediate advantage is that the scheme reduces the indeterminancy associated with external observation to a minimum (section 7.7, for instance makes mention of an indeterminancy about where concepts *are* in a student and teacher interaction). The embarrassment is minimized if student, teacher, concepts, etc. are all represented as conversational *process(es)*. Other merits of the scheme do not appear so immediately. It is, for example, useful, and permissible, to speak of conversations between groups, roles, schools of thought, organizations, cultures and the like; just as it is useful and permissible to speak of conversations between the perspectives *of* a participant.

The scheme is tenable over the domain of conversations, the objects of observation; other commonly recognized entities (such as brains, personalities, and roles; bodies of knowledge, plans for action; particular activities or events), may be represented in these terms with more than usual precision and it looks as though the formulation has considerable generality. However, the scheme is not, and is not claimed to be, exclusive of other schemes.

9. Indeterminacy, information transfer, consciousness and self organization

CT has an object of enquiry, i.e. the conversation, canonically specified in section 8.10.

9.1. THE CHARACTER OF OBSERVATIONAL INDETERMINACY

The primary tasks of CT is to identify conversations, as the proper objects of observation. There is an irreducible indeterminism in doing so, which may either be ascribed to the fact that the objects of observation are autonomous units, also able to converse (and, to that extent, to take part in some other joint autonomy), or, equivalently, to the deliberate and necessary elimination of a hard and fast discrimination between structures and behaviours (the closure condition entails both).

In practice, the possible observables depend upon how much of the *Inftr* can be exteriorized for observation. There is a very real sense in which conversations have to be *captured*, either by participant experimenters or special equipment. The act of capturing a conversation to maximize the data available to an observer is at odds with

the customary fiat, "minimize interaction" because the relevant data, although quantifiable, are subjective data and not, strictly, objective data.

With few exceptions, the observation problem, which plagues all the social, psychological and computational sciences, is misrepresented, so that observational uncertainty appears, spuriously as a "Black Box" indeterminacy associated with an ineluctable structure, or an indigestably complex behaviour. In fact, it is seldom, if ever, legitimate to identify *structures* (such as brains, or egos) or *behaviours* (task performances) with (psychological) unities; generally they are *not* and generally (with the exceptions noted in the Introduction) the pretence that they *are* leads to a facile smudging of the relevant issues.

9.2. PERSPECTIVES

A *participant* determines his focus of attention (a participant is autonomous). What, if anything, can be said about the rules and regularities that govern the process change in the perspectives?

The observational indeterminacy cannot be avoided but something can be said if a few plausible postulates are introduced, to act in the capacity of root axioms in an axiomatic scheme.

One of them (an activity ordinance) is tantamount to existence (here, of a process) and, as such, is beyond particular scientific debate; the proper philosophical and metascientific arguments are ontological (and deal with the *kind* of existent; here, a unitary or autonomous process).

Another, a Conservation Principle *is* open to discussion. Experiential, intuition or based arguments, as well as empirical data, can be employed to support the particular "principle" chosen. Moreover, at the theoretical level, the "principle" we have elected to employ is compatible with (though not quite identical with) a principle of "self organization" which has been advanced, successfully, from several independent quarters.

9.3. PROCESS

By ordinance, a process, with the stability of organizational closure *exists*; that is the executions *Ex* required to satisfy this existence condition, do take place.

This may say a little more than it seems to do at first sight (though the matter is discussed in section 4). Several concurrent processes must take place. These are of different *kinds* of process or different *orders* of execution.

If a process exists, some perspective is adopted.

To see this point, examine Fig. 2 (the scheme for the most elementary formal concept), representing all of the productions and product—return connecting—loops. As such, the scheme could represent $Con_A T$ or $Con_A P$ or $Con_A Q$ and, if regarded as a pattern, it represents all of them at once. However, if the scheme is really executed then it is stable concept; which concept depends upon the immediate locus of control (and, because of the peculiarly spartan and minimal scheme of Fig. 2, only *one* of $Con_A T$, $Con_A P$ and $Con_A Q$ can act as the main or dominant locus of control at once, although this may be *any* one). The one chosen is (arbitrarily) $Con_A T$ because $Con_A T$ is used as a point of agreement; hence, $Con_A P$ and $Con_A Q$ are concepts from which $Con_A T$ "is derived". Such complete symmetry is *not* always available, so that, in general, the dominant $Con_A T$ is ordained, to some extent, by the pattern. But it is *always* the case that "adopting perspectives" does hierarchicalize the system, although not necessarily in this rigid manner.

Any thought, any act of attention, any learning or any behaving involves at least one perspective. Conversely, if (as postulated) a process exists, then there is some concrete or intellectual act that takes place.

Since the observed unity in CT is a conversation, *more* than *one* perspective is adopted, and, leaving the very cogent issue of what an epistemological neighbourhood *is* until the later paper, these perspectives are near enough to be juxtaposed and may be resolved in an agreement (one of the types examined in sections 7 and 8).

9.4. BOUNDARY CONDITIONS AND SOME BASIC CONSERVATION PRINCIPLES

What commodity is conserved or maximized in the operation of an organizationally closed and informationally open system?

As a direct consequence of selecting a *conversation* (involving, necessarily, more than one perspective) as the unit of observation, we are *bound* to select (Petri) information transfer as the conserved quantity. We require that an information flux exists, for any unity which counts, during an observation, as an organizationally closed and informationally open system.

9.5. INFORMATION TRANSFER

An interesting interpretation is possible if not, in fact, mandatory.

The quantity "information transfer", *between* the autonomous (organizationally closed or stable) systems *is* what we normally call consciousness, and it may be quantified by any convenient method, though there is some precedent for exteriorization techniques. Whatever method is employed, the quantifying numbers are strictly designators of a subjective quantity.

The information flux trapped within the closure of such a system *is* an awareness; since, in general, a degree of awareness cannot be exteriorized except by indirect methods it cannot, in general, be quantified, although it is quite a simple matter to specify when it will be reported.

For this purpose look back to the enigmatic labels (a), (b), (c), (d) attached to Fig. 1. Think of a skill either intellectual, or manual (addition, memorizing, driving, typing, for example). If the skill of T (the $Con_A T$ in Fig. 1) is overlearned, then its execution is unconscious. Typically A (the participant shown in Fig. 1) can talk, or do other things, whilst performing these skills. Quite the reverse is the case if the skill is instructed *de novo*, for example, by some tutorial algorithm, as in (a) of Fig. 1. This is a readily recalled event, for most people, in the context of driving, adding and typing, probably not at all readily recalled for memorizing unless, at some stage, the individual has learned speed reading, or mnemonic methods [it would have been perfectly familiar to the students at Rehetoric schools, as noted by Yates (1966) in *The Art of Memory*].

Another event of which we are aware is the discovery of significant variants, methods, or algorithms, for doing the same task, and for embedding the task into a conceptual repertoire. It is quite easy to stimulate A's awareness by requesting A to discover a fresh method [the label (b) in Fig. 1] and a similar result is obtained if A is asked to teach a novice (at least, for driving or typing where A can plausibly act the part of an instructor). The general production of a later reproduced novel method *or* the *provision* of a novel

method of doing what is done already is shown at (c) in Fig. 1; once again, awareness is readily and predictably, stimulated.

Suppose the skill is executed without awareness but that a behaviour or conceptualization is unsatisfactory; in the case of arithmetical addition, for example, the numbers do not form a sum; in the case of driving a motor car, there is a collision or a traffic misdemenour. Again, A is aware of this fact for he must revise his skill by enlarging $Con_A T$. This possibility is shown as label (d), in Fig. 1.

It is asserted, by inference from the postulates, that awareness is contingent upon (a), (b), (c), (d), in Fig. 1, and is manifest if and only if these events take place.

Consciousness which *is* quantifiable, is A's awareness *with* B (or B's with A) *of* some agreed ostension, T. Its degree is a measure of information transfer. Its cognitive content is the collection of procedures that are conversationally exchanged.

Section 9.8 includes a comment upon the missing part, namely an affective, or emotive, content of any conscious event.

9.6. SELF ORGANIZATION

Von Foerster (1960) advocated a simple criterion for self organization; arguing that any index of organization necessarily involves a ratio between the actual and the possible complexities or information *indices*. Since the redundancy, R, has this property, where

$$R = 1 - H/H_{max} \text{ (H information index, } H_{max} \text{ its maximum).}$$

Von Foerster proposed that a system is self organizing if and only if the rate of change of redundancy is positive. For a constant valued H_{max}, the condition is secured only if H is decreasing; for constant H, only if H_{max} is increasing.

The apparent simplicity is deceptive; for how, in fact, is the quantity H_{max} to be increased when (as must occur in any convergent or adapting organization) dH/dt tends to zero. The reply is, of course, a change in the state description of the system, or, in case the system is alive, in some global quality, like its focus of attention or the formulation of a further problem once a problem is solved. These interpretations are spelled out for individual and society-like-systems, in Von Foerster & Pask (1960, 1961) and quite widely exploited in empirical studies of adaptive training, testing and group regulation (Lewis & Pask, 1964, 1968; Pask, 1972). Very broadly, changes of attention led to the revaluation of H_{max} and changes of H were estimated by several methods (frequency of response, degree of belief estimates), relative to the prevailing focus of attention and value of H_{max}. There is a recent paper on self organization (Sahal, 1979) which goes a little further than our mainly empirical methods, but as a mathematical development. Nicolis & Prigogine (1977) and Nicolis & Protonotarios (1978) have independently developed criteria for self organization, from a different starting point, and it is probably fair to comment that any modular hierarchical system (Cainiello, 1977) has a characterization at the thermodynamic level; hence, a fully fledged organization and self organization index.

9.7. RELATIONS BETWEEN SELF ORGANIZATION, COHERENCE AND PETRI INFORMATION TRANSFER

Self organization is often, and rightly, considered to be an index of animation; the extent to which a system is living. Obviously, any organizationally closed system like a stable concept will be self organizing as it approaches coherence and parallel execution since indices like H will surely decrease to zero during this regime. The same comment applies to an average of H, over some ensemble of organizationally closed systems all of which are in the same coherence-approaching regime, especially, if instead of remaining independent, they interact by agreement. However, we are up against te problem encountered in the earlier work by Lewis and myself, namely, that this coherency-approaching adaptation eventually gives rise to an unchanging state of affairs (further, if there is agreement amongst the ensemble of organizationally closed systems) to a uniform state of affairs when $dH/dt = 0$.

Lewis and myself dealt with this problem in an empirical context, by noting that learners, for example, change their focus of attention and that when they do so H_{max} is *respecified* and (assuming that what has been learned is retained, H_{max} is increased) so that $dR/dt > 0$. At that stage, we had no fully satisfactory method for dealing with the matter; for the approach we adopted suffered from the same arbitrariness in change of variables as the approach of Nicolis, Protonotarios & Theologou (1978). Undoubtedly, they have made an important advance by noting that a change must occur at points of essential (catastrophic) bifurcation on *mathematical* grounds; whereas our own reasoning depended upon an empirical observation.

However, their model is also arbitrary, to the extent that no mechanism exists for *effecting* these changes, and such a mechanism cannot exist, in principle, due to the mathematical assumptions that are used to implement or (as it stands) to simulate the model. This point is worth pursuing because it seems likely that rather small alterations in the essential postulates would eliminate this restriction.

Consider an ensemble of organizationally closed and informationally open systems in conversation, i.e. the type of system regarded in this paper as one of the canonical participants. The conversations will lead to a general homogenization of the ensemble, insofar as they lead to agreement between the participants. However, each conversation is *initiated* by an essential bifurcation and a novel distinction. Further, some of them *lead* to essential bifurcations, the number of which increases with the degree of homogenity. Any bifurcation respecifies H_{max} and, given the tendency to coherence, increases it.

We cannot assign an absolute value to the index H_{max}, because the fundamental structure-behaviour-indeterminancy prohibits this measurement. However, we *can* estimate the Petri type information transfer between organizationally-closed and informationally-open systems, that takes place across the distinctions constructed. At least we can provided that the systems are *genuinely* rendered independent and asynchronous by these distinctions, until the disparity is remedied by agreements between participants.

This is where the constraints of the Nicolis & Protonotarios model, introduced as a prerequisite of mathematical elegance, render the model defective, although, by relinquishing some of them, the defects could, so far as I can see, be quite easily remedied. The trouble is that these constraints, which permit cross-correlation, averaging and other standard techniques, also prohibit the direct estimation of a Petri type information transfer and, consequently, disallow the type of observations that are needed in order to avoid an arbitrary frame of reference (or choice of higher level variables).

It is true that the model could not be computer simulated *without* the mathematical *assumptions*, but the point is that the Nicolis & Protonatarios model is potentially much more perspicuous than its simulations (interesting and useful as they are). It is *not* limited to implementations that *are* simulations in the sense of "serial simulations" (for that matter, neither the team decision system, nor THOUGHTSTICKER, *is* or *can* be, realized in *one* standard computer; the Nicolis & Protonotarios model *can* be realized in the equipment employed for these systems).

As a positive proposal, let us return to Von Foerster's formulation, of a self organizing system with its separable conditions, namely, that (a) $0 > dH/dt$ (H_{max} constant) and (b) $dH_{max}/dt > 0$ (H constant), so that $dR/dt > 0$. Of these, (a) represents the existence of an L computing medium with a tendency to coherent execution; more generally, to the mechanism of coherence or agreement. On the other hand, (b) is a mathematical token for distinctions ensuing from essential process bifurcations that are *bound* to occur if the process *becomes* homogeneous. Although the fundamental indeterminancy (the structure behaviour indeterminancy of CT) disallows the absolute valuation of an H_{max} (its best estimate is an asympotic value of H, and is quite arbitrary), it *is* possible to observe the Petri type information transfer, directly, as the consciousness manifest in a conversation. Although any observations of this type are subjective, (as they are "I-and-you referenced," not "*it* referenced") this does not render them unscientific unless one adheres to a narrowly-blinkered view of science, which would prove untenable even in many of the older scientific disciplines, like physics. At any rate, regardless of the view that is preferred, these observations are open to as much refinement and quantification as desired within the limit imposed by "capturing" a conversation or "exteriorizing" it for observation.

9.8. SOME REFINEMENTS

In the last resort (however much observers act as participants), the boundary of an organizationally closed and informationally open system is revealed by the appearance of information transfer.

It has been argued that a rate of change of organization (or transfer) applies to all such systems, thereby invoking a common time co-ordinate, with one infinitesimal dt (rather than dt_A, dt_B for systems A, B, . . .). At best this is an oversimplification, and it *may* be a *contradiction* since the autonomous (organizationally closed) units are initially of an asynchronous (or independent) kind. In fact, it is the blurring of dt_A, dt_B, . . . which is the chief objection to one aspect of Nicolis' model.

There is no serious difficulty in giving A, B, . . . (when they are revealed) distinct time coordinates t_A, t_B . . . or the distinct infinitesimals dt_A, dt_B, . . . , which is tantamount to taking the Petri-type information-transfer seriously, and countenancing consciousness as something in CT rather than placing it in a metatheory or even taking it for granted and saying no more. However, this expedient may not be enough.

Atkin (1973, 1977) has developed a sophisticated topological model (or language, as he prefers to call it, with a good deal of practical justification) for dealing with relations between data of any kind. Whereas Atkin uses set membership (in fact invoking universal consensus over a membership test, on data or other entities), we shall use the sharp valued observable coherence condition and, as a result, identify the elements of Atkin's sets with agreements over *understandings*, or their indefinite iterates, *topics*.

Given this, which is entirely compatible with the model (or language) in question, it is legitimate to make appeal to a piece of theory (Atkin, 1973, 1977) that is erected in terms of the topological language. Atkin's theory is concerned with the dimensionality of events in general, but in particular with the appropriate *time* "in which" these events are placed; for example, Newtonian point interval *time* (the common time previously introduced), is a 1 simplex comprising instants linearly related by intervals. Atkin (rightly so far as I can see) suggests that Newtonian time (or, for that matter, the much more complex time structure of relativity theory) is quite unsuitable for accommodating the events typical of social or psychological systems, and he gives a general time structure definition (as an ordering over p simplices, which is a full ordering of events).

Thus, not only are t_A and t_B distinct but the structure of t_A and t_B are generally different (though, given the argument in my future paper, these structures can be specified). It is conjectured that the time structure of events in a given, organizationally-closed and informationally-open system, *is* the crucial feature of affect, the "missing aspect" of consciousness (here, the cognitive component comprises the procedures exchanged between A and B). There is strong evidence from Jacques' (1956) study of time span (a projection of the proper individual structures onto a 1 simplex) that this is so, and our own findings, in decision, support the same hypothesis.

The implied exchangeability of consciousness, time structure, and information, is the subject of some ongoing research in this laboratory, and other institutions.

10. The curious status of doubt

The state of mind "awareness" may go under several names, such as "aperception" or "attention" (as used to designate "a state of mind" rather than "a focus") or "anticipation" or, conversely, "salience in memory". Awareness is interpreted in section 9.4 as the conserved quantity, or commodity, of CT and identified, in section 9.5, as Petri type information transfer between perspectives or loci of control in an L processor (typically, a brain). The following section is concerned with the manifestation and quantification of this Petri type Information Transfer.

The primordial manifestation of awareness is "being certain about the continuity of personal experience of any kind" (insofar as the perceptual aparatus is a sampling filter, servosystem, or whatever), there is no logical, or empirical, *justification* for this belief although our behaviour would be impaired if we did *not* subscribe to it.

Such an identification, between awareness and certainty, is scarcely interpretable unless you (the reader) have experienced the opposite condition; for the myth of continuous existence, is deeply, and fortunately, ingrained. The opposite, "being in doubt about continuity of awareness", is a condition encountered after prolonged spells of wakefulness, so far as I am concerned, after some 50 or 60 hours on duty, but there seems to be a large individual variation. At this stage, the usual and harmless manifestation is awareness of brief "cat naps", important events seldom go unnoticed.

However, as fatigue increases, you do begin to doubt that you will be aware "at the next moment" (whatever *that* means) which appears to be quite a common experience amongst people accustomed to prolonged duty periods.

This "primordial certainty" is undifferentiated. I am certain that a process, my mind, goes on, and without greater specificity do not, and cannot, say what that process is. Specialized types of certainty or doubt refer to named entities, situations, objects events, etc. For example, "I am certain that I am in the Marylebone Road" or "I am certain that either I am in Luxborough St., or the street running adjacent to it": both of which are tacitly qualified by a certainty that I am aware. On further specialization and

refinement, the qualifier is omitted, as redundant, and "I am certain this is Baker St. Station in the Marylebone Road, not some other station on the Tube", or "I am doubtful whether this is Luxborough St. or Buckingham St., but certain that it is one or the other". Still, however, the undifferentiated, essentially descriptive character of doubt, or certainty, is retained. The streets might be processes, or events, or propositions, but my doubt or certainty does not explain their nature or connection, (of course, the referent of doubt or certainty may *be* an explanation; for example, that Buckingham St. runs parallel to Luxborough St., that they are connected through Nottingham St., that they are one block apart from each other. I may be doubtful about the verisimilitude or the contextual adequacy of the explanation I give; for instance, can a recipient find the way from one street to another.) Nearly always, since behaviour involves action, we have doubts or certainties about several entities and several kinds of entity (for example, places, their ambience or nature, explanations of their geographical location).

Commentaries of subjects in psychological experiments, or of professionals engaged in skills, like "commentary driving", that have a component of verbal reporting upon performance are, also, unanimous in vouching for the many faceted, as well as the varying qualities of their experience of doubt or certitude, and it is curious to note a pervasive belief that it is *usually* or *normally* possible to index the certainty of awareness by *one variable* "confidence" (and its converse quality "uncertainty") as a measure of *one kind* of subjective probability. This belief goes hand-in-hand with another strange conventional wisdom; namely, that the differentiated entities (Luxborough St. and Buckingham St., for example), may *usually* or *normally* be replaced by a set of alternatives *given* by an experimenter (such as alternative responses or alternative answers to a question).

The protagonists of univariate certainty and uncertainty appear to be mislead by an elegant mathematical modelling technique. At the point where the certainty of awareness is differentiated from the flux of mental activity into referent objects, events, etc. that someone is "uncertain about", it *is* possible to imagine "freezing out" the process, as a "choice situation". Under these circumstances, (both the differentiation and the "freezing out" being assumed) the choice situation can be *modelled* as a set of alternatives; choice, as a selection of one and only one at once. If so, then, as a mathematical truth, it is appropriate to employ a probability measure (assigning a fractional number to each alternative such that the sum of the fractions is unity). It is all very valuable, expecially if embedded in the beautiful edifice of the probability calculus. However, this mathematical model does not imply that a "simple selection" is a *psychologically* simple "choice event"; it does not imply that probabilities or derived uncertainties are indicators of a univariate *psychological* quantity.

Over and above the evidence of experience there is no empirical warrant for such a simple index. This becomes evident on looking in detail at one of the situations often regarded as peculiarly simple and amenable to unambiguous confidence estimation, namely, a multiple choice examination.

If people doing such an examination are interrupted, and asked how they select a response, then some subjects undoubtedly reply that they answered the question by "biased guesswork" or by "intuitive hunch". How many of them do so depends (amongst other things) upon the question, the interval allowed for response, and the training of the subject. Only if the conditions of response are paced to minimize response time, [as in Hick's (1952) work on information and "disjunctive" choice reaction time], does this become the dominant, or usual, reply. Although it may be possible, at any rate in principle, to control the response interval so that just these conditions are obtained this expedient would be incompatible with an attempt to examine someone's knowledge of the subject about which the questions are posed.

Conversely, by increasing the time allowed (the opposite of the disjunctive reaction time experiments) and, for preference, using an other-than-multiple-choice examination, guesswork can be virtually eliminated. For example, in an examination where the subjects know how problems are to be solved and are expected to have a correct score of nearly 100% [as an illustration, the survey examination of the Institute of Mathematics and Its Applications (1978)] it is possible, at least for mathematical topics, to approximate this ideal. It may be recalled that the result of the Institute's experimental examination was extremely strong, just because students failed the examination, (even under these near-to-optimal circumstances), being unable to *do* what they are believed to know, on the basis of test assessment, or otherwise.

10.1. GUESSES AND METHODS

In any case, under classroom conditions, when subjects are simply asked to respond as quickly as possible, replies to "How or why did you respond that way?" are not usually of the kind "hunch or biased guesswork". The other replies are aggregated, in Table 1, into "Solution method" (which differs with the question) and "Elimination Trick" (which is a pre-learned, or pre-trained, examination technique where choice depends, primarily, upon the structure of the test, rather than the content of the test questions).

TABLE 1

Records from 68 subjects each interrupted on one occasion per material (mathematical, linguistic, and definition)

	Biased guesswork or hunch	Solution method	Elimination trick
Mathematical problems	12	22	34
Visual and logical test Raven matrices	18	27	23
An IQ type of test	6	27	35

As a further observation, different subjects use different solution methods to solve the *same* problem, and some subjects contemplate several different methods and are unsure of which one to use. Similar comments apply to the elmination tricks employed, though there is less variability.

For example, the mathematical type multiple choice question, "$\sqrt{4\cdot 84}$ = one of 2·2 or 2·3 or 1·8", can be correctly answered in any of several ways, as, for instance by squaring the numbers and comparing them with 4·84, by using a square root algorithm, by approximation and successive exclusion, or even by noting that 2·2 fits into the descriptive equation. The latter solution *only* could be deemed informed guesswork,

and is unequivocably descriptive. No method is made explicit. One of the alternatives simply looks balanced.

Again, although there is no uniquely correct response to the multiple choice question "Intelligence Test" is most reasonably described as one of:

(a) the quality of intellect or
(b) the quantity measured by a psychological test or
(c) an ability to reason logically.

There are many non-mathematical methods of testing the propositions for plausibility, and a distinct, description matching operation that qualifies as informed guesswork.

Table 1 is not intended to be representative of a population. The entries could be changed by a small, and perhaps unnoticeable, alteration in the conditions. Instead, readers are encouraged to look for themselves at what *does* go on (rather than what is officially meant to go on), and to draw their own conclusions in the matter.

The significant differences in Table 1 suggest that people commonly address problems in quite different ways and they are in more or less doubt about each of them. At one extreme, there are some people who seem to contemplate the alternatives and to guess with no rule in mind; to them, the question topic is described and a properly constructed set of alternatives is a collection, all of which are plausible candidates, but only one of which fits the description. For them, there is either *no* method or a legion of methods, too numerous to delineate. At another extreme, there are people who apply one or more methods which may either be genuinely relevant to the problem, or else primarily relevant to making a high-scoring selection amongst the alternative-responses.

In view of these findings, it seems odd to suppose that there is one *kind* of doubt about the answer to a question.

10.2. TYPE OF DOUBT/CERTAINTY

For complex decision making, it turns out (as is argued later), that the pertinent kinds of doubt (conversely, the kinds of certainty) are very varied and numerous. It is also worth noting that most human decision making *is* very *complex*; the situations engineered in Casinos and Poker play (and imitated by all multiple choice tests) are seldom encountered and human behaviour, in these situations, is atypical, unless regularized by special training (in gambling, in questionnaire responding). It is also relevant to contemplate laboratory studies of rewarded guessing and to note that frequency matching (as a pure response mode) occurs rarely, and never over a protracted interval; that statistician-like behaviour (choose the most rewarded, always), is common, and that superstitious behaviour is most often observed.

However, given a multiple-choice situation, and subjects who are familiar with the response format, there is substantial consensus amongst them regarding a distinction between at least two kinds of doubt (conversely, certainty) that are commonly encountered when answering questions.

The two kinds, the distinctions of which are consistently emphasized, are, as suggested before, (I) a descriptive doubt (whether the alternative fits in), which is associated with the alternative set and is not contingent upon a rule or method. As reported, this is doubt about a hunch, not, in any sense, about a procedure. A confidence or degree of belief estimate is *supposed* to, may, and probably *does* index this particular doubt. (II) A doubt about which rule to use *or* about the character of a rule (which, if applied, is known to solve a problem) *or* (and, here in contrast to Table 1, no discrimination is attempted) a doubt, about exclusion or elimination tricks, learned with the response format.

From the discussion of stable concepts and their development, a number of strong predictions can be made in terms of these doubt/certainty types, (I) and (II), about changes in type of doubt as a stable concept is learned; namely, a concept of the topic on which a question is based. These hypotheses have already been introduced by appeal to everyday experience, namely, a regular progression from knowing *nothing*, to knowing and being *certain* over a description [a decrease in type (I) doubt] to knowing and becoming certain about *one* method [a reduction in type (II) doubt], to knowing and being *less* certain about, a multitude of methods [a subsequent increase in type (II) doubt]. An empirical test of this progression is entirely possible.

The trouble is that it takes a long while to learn fully, and overlearn, a concept. The process has been studied over a period of months, in individual students who first understood an academic concept at a known instant. Such experiments require commitment and are laborious, so that only a couple of dozen have been carried out, systematically, with the environment of CASTE, in the laboratory, and, in an institutional setting, with the aid of INTUITION. Both systems can provide many-dimensional indices of doubt. At the level of perceptual motor skills, such as typing and driving the concepts, or subskills, are overlearned more rapidly, but studies of well over 1 week are usually needed before the initial subskills, whether of tracking, typing or vehicle control, become automatic and executed by a large but coherent cluster of procedures. Once again, some data exist but for relatively few individuals (Pask, Scott & Kallikourdis, 1973*a*; Pask, 1975*a*; Pask *et al.*, 1976/79).

To check these findings for a larger group of subjects, an experiment was carried out, relying upon the discrimination of doubt types (I) and (II). For this purpose, a multiple choice examination was constructed from 12 (each) mathematical and definitional questions (pilot studied for their intelligibility), preceded by a response-practice-block, of 10 questions.

10.3. AN EXPERIMENT

The examination questions are answered and the subject is asked to state how certain (how little in doubt) he is about the *method* used; if there is no method, the *certainty* is zero. It would be possible, also, to ask for a confidence estimate over the response alternatives, as an index of inspired guesswork, but, since Shannon information measures over such alternative sets are reliability monotone-related to a latency based information measure it was legitimate, and less burdensome, to employ the logarithm of response latency as the index of informed guessing in selection. Doubt of type (I) is thus estimated by the logarithm of response latency, and doubt type (II) by a rating of certainty about method, on a scale of 1–5, presented after each response.

The examination was individually administered to 64 subjects. After each part of the examination subjects ranked the *familiarity* of *each* of the 12 topics about which questions had been asked. The interpretation of familiarity consists in "how long you have known and used the corresponding concept". As a rule, subjects tend to rank familiarity by their impression of, "how long ago the concept was learned".

It was predicted that Doubt of Type (I) does not co-vary with Doubt of Type (II) when these quantities are plotted against the age of a stable concept, however, that regular (but different) changes take place as the concept is overlearned, where concept "age" is estimated by the ranked familiarity of topics.

Notice that no assumptions are made about the difficulty of the topics involved. Individuals do find some topics considerably more *personally* difficult to handle than others and the impression of difficulty is, perhaps, indirectly indicated by the familiarity rating. This *personal* difficulty may even be self-consistent but, apart from a few mathematical questions, the ranks assigned by different subjects are not very similar.

There is no evidence, except for some mathematical topics, to favour an *absolute* difficulty and cross personal regularities, are reduced if subjects are encouraged to regard the situation as a study of cognitive-method, or problem-solving style, rather than a test of ability (it looks as though the remaining cross-personal correlation can be accounted for in terms of educational experience).

The data in Table 2 support the hypothesized trends although, as might be expected, there is a difference between the mean value and the variability of the data for different types of question and topic.

10.4. SOME GENERAL EMPIRICAL COMMENTS ON DOUBT AND CERTAINTY

The word "uncertainty" has been corrupted in several ways by usage in the literature. It generally means any kind of information measure calculated from objective frequencies or subjective (i.e. confidence estimated) probabilities. The frequency interpretation is unequivocally an index of variation, an uncertainty or conversely an information, to an external observer. The latter is ideally the subject's uncertainty (although the generality of this interpretation is seriously questioned). The referent of uncertainties calculated from response latencies or studies of receiver operating curves is ambiguous unless stringent precautions are taken (when, under particular conditions, the indices are subjective in type). Whatever else, the clarity, or degree, of awareness is not like the uncertainty we experience in respect to an aleatory event (the outcome of a horse race, the resting position of a roulette wheel).

In the sequel, doubt/certainty is used as the polar attribute of the *clarity*, or the *degree*, of awareness, and it is assumed that doubt/uncertainty is a many, and variably, dimensioned attribute. This usage has been adopted for the very simple-minded situations which have been considered in this section, but the issue has greater and more foundational consequences at the level of complex observations or experiments which are more typical of CT, the studies outlined and summarized in the fourth paper and the studies reported in the fifth paper of the series.

So, for example, the comments in section 10 suggest that even if a latency is employed to index doubt/certainty (as in Table 2), then only under particular circumstances (for instance, those in which the data of Table 2 is obtained), will it be legitimate to have a "one-dimensional" or "point interval" latency; in general, latency is many dimensional, and doubt/certainty is many-dimensional, as a result.

The fact is that if the arguments of section 10 are really taken seriously (albeit as hypotheses to be supported or denied), a great deal of the pre-suppositional structure of psychology, education, sociology, and the related sciences, is necessarily modified; different kinds of enquiry, for example, have significance. The present discussion of doubt/certainty and the like is only symptomatic of a more basic reappraisal of the

TABLE 2

	Most Familiar 1 A	1 B	1 C	1 D	2 A	2 B	2 C	2 D	3 A	3 B	3 C	3 D	4 A	4 B	4 C	4 D	Least Familiar 5 A	5 B	5 C	5 D
Mathematical logical	4·65			1·15	2·20			1·34	2·01			1·07	3·26			2·05	3·40			1·10
		1·81		1·50		4·47		1·22		4·33		1·84		1·57		1·12		1·59		1·05
			4·34				2·11				2·54				2·82				2·23	
General definitional	4·24			0·60	4·00			0·88	1·39			1·34	2·11			1·49	2·24			0·52
		2·56		0·40		3·02		0·75		2·25		1·89		4·35		2·50		2·91		0·52

1 Most familiar — 2 — 3 — 4 — 5 Least familiar

E = Ranking of topic familiarity

A = Doubt/certainty type (a) by index logorithm of latency (lower the more certain the subject is) either correct or mistaken response.
B = Doubt/certainty type (b) by rating confidence estimates.
C = Doubt Type (a) correct only (inapplicable unless mathematical logical).
D = Standard Deviations of scores (high and uninterpretable for C index).
E = Familiarity (horizontal coordinate) as ranking of all topics of a given type at the end of relevant part of the examination. For topics assigned the highest and the lowest ranks of familiarity there is significant rank correlation between subjects but not for the central ranks.

structure underlying fundamental postulates, such as the proper identification of autonomous (individual) unities, and the criteria for independence of data samples. These broader issues will be discussed, in later papers in the context of experiments *with* or applications *of* CT, either in the laboratory, or in real life.

The crux of the matter can be phrased, in a slightly colourful way, as a plain question to the reader. Are you more impressed by an accumulation of data, such as Table 2, extended to whatever limit, than you are by a recipe describing an experiment which, knowing the state *of* your mind, can always yield a consistent result *in* your mind? As an alternative to the personal experiment, you may prefer (and may substitute) a recipe which, if it is agreed by someone with whom you converse (and to that extent know your joint state of mind), will lead to a determinable result, such as a change in attitude, or behaviour.

A practical man, concerned with cognition, behaviour and society, can nearly always make more use of the recipe that works conditional upon some state of knowing, either one that is apparent, or one to be discovered. CT, being reflective and relativisitic provides working recipes of this type, and claims to explain why they do work.

CT may also furnish hard objective data, although the necessary experimentation is quite arduous, because the hard-nosed things of CT are conversations, and because the hard nosed observable data points are (subjective) agreements over an understanding. Sometimes, it *is* possible to arrange matters, as in the laborious *individual* studies cited in section 10.2, so that events come in one-to-one correspondence with agreements over understandings.

Notice, however, that frequencies of events or correlations between events are not usually CT-hard data, for example, the data in Table 1 and Table 2 are not CT-hard data, and they do not become harder, in these terms, as a result of any statistical manipulation.

References

ANDREKA, H., GERGELY, T. & NEMETI, I. (numerous papers 1975–1980), (also MARKUSZ & SZOTS, and others) are most readily available in the English language journal *Computational Linguistics and Computer Science* of the Hungarian Academy of Sciences, Budapest.

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

ATKIN, R. H. (1977). *Combinatorial Connectivities in Social Systems*. London: Heinemann.

AQVIST, L. (1971). Revised foundations for imperative-epistemic and interrogative logic. *Theoria*, **37**, 33.

BANNISTER, D., Ed. (1970). *Perspectives in Personal Construct Theory*. London: Academic Press.

BANNISTER, D. & MAIR, J. (1968). *The Evaluation of Personal Constructs*. New York: Academic Press.

BARTLETT, F. C. (1932). *Remembering*. Cambridge: Cambridge University Press.

BATESON, G. (1973). *Steps Towards an Ecology of Mind*. New York: Paladin.

BATESON, M. C. (1972). *Our Own Metaphor*. New York: A. Knopf.

BELNAP, N. D. (1969). Aqvist's corrections—accumulating question-sequences. In DAVIS, J. W. *et al.*, Eds, *Philosophical Logic*. Dordrecht: Reidel.

BOXER, P. J. (1979). *Supporting Reflective Learning: Towards a Reflexive Theory of Form*. Human Relations, Tavistock Inst. (in press).

BRADLEY, F. H. (1914). *Essays on Truth and Reality*. Oxford: Oxford University Press.

BRATEN, S. (1977). The Human Dyad. Systems and Simulations. Inst. Sociology, University of Oslo.

BRATEN, S. (1978). Competing modes of cognition and communication in simulated and self reflective systems. *Proceedings, Third ARI Conference on Decision Making in Complex Systems*. Richmond, August. Richmond: System Research Ltd (publ. 1979).
BROWN, J. (1977). *Mind, Brain and Consciousness*. London: Academic Press.
BRUNER, J. (1974). *Beyond the Information Given*. London: George Allen and Unwin.
BYSHOVSKY, V. K. (1974). Control and information processing in asynchronous processor networks. *Proceedings, Finland USSR Symposium on Micro Processors and Data Processors*, Helsinki, Vol. 1 (distrib. 1974).
CAINIELLO, E. (1977). Some remarks on organisation and structure. Inst. Theoretical Physics, University of Alberta, Canada (as sabbatical project), Lab. for Cybernetics, CNR, Naples.
COHEN, J. (1974). Reflections on the structure of mind. *Scientia*, **5–8**, 1–23.
CONWAY, J. H. (1970). Game of life. *Scientific American* (October). (See also, GARDNER, M. *Scientific American* (February 1971).)
DANIEL, J. S. (1975*a*). Conversations, individuals and knowables: toward a theory of learning. *Engineering Education*, 415–420 (February).
DANIEL, J. S. (1975*b*). Learning styles and strategies: the work of Gordon Pask. In ENTWISTLE, N. & HOUNSELL, D., Eds, *How Students Learn*. Lancaster: IPCE, pp. 83–92.
DUNCKER, K. (1945). *On Problem Solving*. Rep. 1972. West Port, Conn.: Greenwood Press.
EASTERBROOK, J. (1978). *Determinants of Free Will*. London: Academic Press.
ENTWISTLE, N. J. (1976). Editorial introduction to symposium learning processes and strategies—1, The verb, 'to learn', takes the accusative. *Br. J. educ. Psychol.*, **46**, 1–3.
ENTWISTLE, N. J. (1978). Symposium: knowledge structures and styles of learning: a summary of Pask's recent research. *Br. J. educ. Psychol.*, **48**, 1–10.
ENTWISTLE, N. J. & HOUNSELL, D. J., Eds. (1975). *How Students Learn*. Lancaster: IPCE.
FESTINGER, L. (1972). *Cognitive Dissonance*. Stanford: Standford University Press.
FLORES, C. F. & WINOGRAD, T. (1978). *Understanding Cognition as Understanding*. Report, University of Stanford.
FOGEL, L. J., OWENS, A. J. & WALSH, M. J. (1966). *Artificial Intelligence Through Simulated Evolution*. New York: Wiley.
GAINES, B. R. (1976). *Foundations of Fuzzy Reasoning*. Man Machine Systems Laboratory, University of Essex.
GAINES, B. R. (1978). Decision: foundation and practice. *Proceedings, 3rd ARI Richmond Conference on Decision Making in Complex Systems*, Richmond, (August).
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.
GLANVILLE, R. (1979). The same is different. In ZELENY, M, Ed., *Autopoiesis*, (in press).
GLANVILLE, R. & JACKSON, P. (1977). A theory of model dimensions applied to relational data bases. *Proceedings, 4th Conference of WOGSC*, Amsterdam.
GOGUEN, J. A. (1975). Objects. *Int. J. Gen. Systems*, **1**, 237–243.
GREGORY, R. L. (1970). *The Intelligent Eye*. London: Weidenfeld and Nicolson.
HARRAH, D. (1973). The logic of questions and its relevance to instructional science. *Instrum. Sci.*, **1**(4), 447–468.
HEBB, D. O. (1949). *The Organisation of Behaviour*. London: Wiley..
HELSON, H. (1964). *Adaptation Level Theory*. London: Harper and Row.
HICK, W. E. (1952). On the rate of gain of information. *Quart. J. Exp. Psychol.*, **4**, 11–26.
HOLT, A. W. (1968). *Final Report for the Info. System Theory Project*. Rome Air Development Centre. Contract AF 30(602) 4211.
HOLT, A. W. (1972). Comments. In BATESON, M. C., Ed., *Our Own Metaphor*. New York: A. Knopf.
HOLT, A. W. & COMMONER, F. (1972). *Events and Conditions*. Info. System Theory Project, Appl. Data Res. Inc., New York, Contract DAH–CO4–68–C–0043.
HOWE, J. A. M. & YOUNG. R. M. (1976). *Progress in Cognitive Development*. DAI Res. Rept No. 17, SSRC Grant 2578/2.
INSTITUTE OF MATHEMATICS (1978). Report: Institute of Mathematics and its Applications, Southend-on-Sea.

JACQUES, E. (1956). *Measurement and Responsibility*. London: Tavistock.
KELLY, G. A. (1955). *The Psychology of Personal Constructs*, Vols 1 and 2. New York: Norton.
KLAHR, D. (1977). Modelling the acquisition of problem solving ability in children. *Proceedings, NATO Structural and Process Theories of Complex Human Behaviour*. Alphan aan den Rijn: Noordhoff.
LAING, R. (1961). *Self and Others*. Tavistock, London.
LEWIS, B. N. & PASK, G. (1964). The development of communication skills under adaptively controlled conditions. *Programmed Learning*, **1**, 69–88.
LEWIS, B. N. & PASK, G. (1968). The use of a null point method to study the acquisition of simple and complex transformation skills. *Brit. J. Math. and Stat. Psychol.*, **21**, 61–81.
LEWIS, B. N. & PASK, G. (1969). The self organisation of a three person task oriented group. *The Simulation of Human Behaviour*. Paris: Dunod, pp. 291–311.
LURIA, G. R. (1961). *The Role of Speech in the Regulation of Normal and Abnormal Behaviour*. London: Pergamon Press.
LURIA, G. R. (1968). *The Mind of a Mnemonist*. New York: Basic Books.
MARTIN, R. L. (1963). *Intension and Decision*. London: Prentice–Hall.
MATURANA, H. R. (1975). The organization of the living: a theory of the living organization. *Int. J. Man–Machine Studies*, **7**, 313–332.
MOSCOVICI, S. (1976). *Social Influence and Social Change*. London: Academic Press.
NEWELL, A. (1973). Production systems: models of control structures. In CHASE, W. G., Ed., *Visual Information Processing*. New York: Academic Press.
NEWELL, A. & SIMON, H. A. (1972). *Human Problem Solving*. London: Prentice–Hall.
NICOLIS, G. & PRIGOGINE, I. (1977). *Self Organisation in Non Equilibrium Systems*. London: Wiley.
NICOLIS, J. S. & PROTONOTARIOS, E. N. (1978). Bifurcations in nonconstantsum games: a trigger for 'self' organisation in cognitive systems. *Proceedings, 2nd Int. Conf. Information and Systems*, Patras, Greece.
NICOLIS, J. S., PROTONOTARIOS, E. N. & THEOLOGOU, M. (1978). Communication between two self organizing systems modelled by controlled Markov chains. *Int. J. Man–Machine Studies*, **10**(4), 343–367.
NORMAN, D. A. *et al.* (1975). *Explorations in Cognition*. San Francisco: Freeman.
NOWAKOWSKA, M. (1975). Syntax and semantics of prosocial behaviour. *Formal Theory of Actions*. Inst. of Organisation, Management and Control, Polish Acad. Sciences (and Lab. of Psychol.).
NOWAKOWSKA, M. (1979). Foundations of formal semiotics. Objects and their verbal copies. Inst. Phil. and Sociology, Polish Academy Sciences.
PASK, G. (1961). *An Approach to Cybernetics*. London: Hutchinson.
PASK, G. (1972). A fresh look at cognition and the individual. *Int. J. Man–Machine Studies*, **4**, 211–216.
PASK, G. (1975*a*). *The Cybernetics of Human Learning and Performance*. London: Hutchinson.
PASK, G. (1975*b*). *Conversation, Cognition and Learning*. Amsterdam and New York: Elsevier.
PASK, G. (1976*a*). Conversational techniques in the study and practice of education. *Brit. J. Educ. Psychol.*, **46**(I), 12–25.
PASK, G. (1976*b*). Styles and strategies of learning. *Brit. J. Educ. Psychol.*, **46**(II), 128–148.
PASK, G. (1976*c*). *Conversation Theory: Applications in Education and Epistemology*. Amsterdam and New York: Elsevier.
PASK, G. (1977). *Problem Solving*. IET Open University and Ford Foundation, New York.
PASK, G. (1979*a*). Consciousness. *Proceedings, 4th European Meeting on Cybernetics and Systems Research. Journal of Cybernetics*, Washington: Hemisphere, pp. 211–258.
PASK, G. (1979*b*). An essay on the kinetics of language as illustrated by a protologic Lp. *Proceedings, Workshop on "Fuzzy Formal Semiotics and Cognitive Processes*. 2nd Congress Int. Ass. Semiotic Studies.
PASK, G. (1979*c*). An essay on the kinetics of language, behaviour and thought. *Proceedings, Silver Anniversary Int. Meeting Society for General Systems Research*.
PASK, G. & SCOTT, B. C. E. (1972). Learning strategies and individual competence. *Int. J. Man–Machine Studies*, **4**, 217–253.

PASK, G., SCOTT, B. C. E. & KALLIKOURDIS, D. (1973*a*). CASTE: a system for exhibiting learning strategies and regulating uncertainty. *Int. J. Man-Machine Studies*, **5**, 17–52.
PASK, G., SCOTT, B. C. E. & KALLIKOURDIS, D. (1973*b*). A theory of conversations and individuals (exemplified by the learning process on CASTE). *Int. J. Man-Machine Studies*, **5**, 443–566.
PASK, G., KALLIKOURDIS, D. & SCOTT, B. C. E. (1975). The representation of knowables. *Int. J. Man-Machine Studies*, **17**, 15–134.
PASK, G. *et al.* (1975). Cartoons. Tests for learning style. Richmond: System Research Ltd.
PASK, G. *et al.* (1976/79). Cognitive mechanisms and behaviours involved in other than institutional learning and using principles of decision. Reports on Grant ARI DAERO 76–G–069.
PEDRETTI, A. (1979). *A Conversation Theoretic Paradigm for Semantic Representations.* (Contains 4 papers, 2 previously published, 1977, 1978.) University of London.
PETRI, G. A. (1964). *Communication with Automata.* Trans. GREENE, F. JR, A supplement to *Tech. Documentary Rep. 1.* Rome Air Development Centre, Contract AF30(602)3324.
PIAGET, J. (1968). *La Structuralisme.* (Transl. MASCHLER, 1971 as *Structuralism.* London: Routledge and Kegan Paul.)
POPPER, K. R. & ECCLES, J. C. (1977). *The Self and its Brain. An Argument for Interactionism.* Berlin: Springer.
PRINCE, G. M. (1970). *The Practice of Creativity.* New York: Collier.
REICHENBACH, H. (1947). *The Philosophy of Space and Time.* London: Dover.
RESCHER, N. (1973). *The Coherence Theory of Truth.* London: Oxford University Press.
ROBINSON, M. J. (1979). Angus, Bertha and Conrad: the cybernetics of power, or politics by any other name. *Proceedings, Silver Anniversary Meeting of SGSR*, London.
SAHAL, D. (1979). A unified theory of self organization. *Journal of Cybernetics*, **9**(2) 127–142.
SCANDURA, J. M. (1973). *Structural Learning*, Vol. I. New York: Gordon and Breach.
SCANDURA, J. M. (1975). *Structural Learning*, Vol. II. New York: Gordon and Breach.
SCHON, D. A. (1963). *Displacement of Concepts.* London: Tavistock Publications.
SHAW, M. L. G. & GAINES, B. R. (1979). Externalizing the personal world: computer aids to epistemology. *Proceedings, Silver Anniversary Meeting Society for General Systems Research*, pp. 136–145.
SHAW, M. L. G. & THOMAS, L. F. (1977). FOCUS on eduucation: an interactive computer system for the development and analysis of repertory grids. *Int. J. Man-Machine Studies*, **10**(2), 139–174.
SIMON, H. A. (1973). *Thinking by computers*, and *Scientific discovery of the psychology of problem solving.* In COLODNY, R. G., Ed., *Mind and Cosmos.* Pittsburgh: University of Pittsburgh Press.
SIMON, H. A. & NEWELL, A. (1971). Human problem solving. *American Psychologist*, **26**, 145–159.
VARELA, F. (1975). A calculus for self reference. *Int. J. Gen. Systems*, **2**, 5–24.
VARELA, F. (1980). *Principles of Biological Autonomy.* North-Holland/Elsevier. (Also gives comprehensive references to collaborators and sources including GOGUEN.)
VON FOERSTER, H. (1960). On self organising systems and their environments. In YOVITTS, M. C. & CAMERON, S., Eds, *Self Organising Systems.* New York: Pergamon Press.
VON FOERSTER, H. (1971). Molecular ethology. In UNGAR, C., Ed., *Molecular Mechanisms of Memory and Learning.* New York: Plenum Press.
VON FOERSTER, H. (1976*a*). Papers on microfiche of collected publications of biological comp. lab. Univ. of Ill., Pub: Blueprint Corp., 821 Bond, Peoria, Ill. 61603.
VON FOERSTER, H. (1976*b*). Objects: tokens for (Eigen) behaviours. *ASC Cybernetics Forum*, Vol. III, Nos 3 and 4, 91–96.
VON FOERSTER, H. & PASK, G. (1960). A predictive model for self organising systems, Part I. *Cybernetica*, **3**(4), 258–300.
VON FOERSTER, H. & PASK, G. (1961). A predictive model for self organising systems, Part II. *Cybernetica*, **4**(1), 20–55.
VON WRIGHT, G. H. (1963). *Norm and Action.* London, Routledge and Kegan Paul.
VYGOTSKY, L. S. (1962). *Thought and Language.* Cambridge, Mass: M.I.T. Press.

WALTER, G. W. (1953). Studies on activity of the brain. In *Cybernetics: Circular, Causal and Feedback Mechanics.* Transl. 1953 JOSIAH MACY JR Foundation Conference, (publ. 1956), pp. 18–32.
WALTER, G. W. (1969). Electric signs of expectancy and decision in the human brain. In OESTREICHER, H. L. & MOORE, D. R., Eds, *Cybernetic Problems in Bionics.* New York: Gordon and Breach.
WERTHEIMER, M. (1961). *Productive Thinking.* Social Science Paperbacks (first publ. 1945).
YATES, F. A. (1966). *The Art of Memory.* London: Routledge and Kegan Paul.
ZADEH, L. A. (1974). A Fuzzy Algorithmic approach to the Definition of Complex or Imprecise Concepts. Elect. Res. Lab., Col. of Eng. UCC. Berkeley.
ZADEH, L. A. (1978). PRUF: a meaning representation language for natural languages. *Int. J. Man-Machine Studies*, **10**(4), 395–461.