Journal of Cybernetics, 9:311-000, 1979

CONSCIOUSNESS

GORDON PASK

System Research Ltd., Richmond, Surrey, England

This paper comes to grips with the perplexing but important issue of consciousness as manifest in human beings and other organisms; in social organizations and, seemingly without degrading the idea, in other-than-biological systems. The possibility of taking such a radical step as to speak of consciousness *within* a theoretical frame, and without resorting to the expedient of relegating consciousness to a metatheory about science, arises from combining various developments in Cybernetics or General System Theory, which, though superficially disparate, have a great deal in common; for example, Goguen's work in category theory (1969, 1975) and the work of Gergely and Nemeti (1977) in nonclassical model theory, the representation, in several different ways, of concurrent (in contrast to serial, or strictly parallel) computation, the work of Varela (1975, 1976), Maturana (1969, 1975), and Von Foerster (1960, 1978), upon organizational closure, Glanville's (1975) notion of objects and self reference and the work done on conversation theory by my own group. This background is assumed to be familiar since a sufficient account appeared in this journal (Pask, 1975a).

Conversation theory (in which a conversation between participants A, B, ... is the minimal and canonical unit open to psychological/social observation) has already been presented to the OSGR. For example, there is a paper (Pask, 1975a) that is an appropriately edited transcript of a symposium at the 1972 Vienna Conference of the OSGR; Pask (1978a,b) describes more recent aspects. General references are Lewis and Pask (1968); Pask (1972, 1975a,b,c, 1976a,b,c, 1977a,b,c, 1978a,b; Pask and Scot 1972, 1973; Pask, Scott, and Kallikourdis 1973, 1975). Apart from detailing a few essential points, the theory and its empirical support will, thus, be taken for granted.

In the past, several equally legitimate reasons have been given for introducing conversation theory at all; pragmatic reasons, insofar as its

predictions and prescriptions prove useful in respect to learning, education, design, decision, and the like; foundational reasons, insofar as "mainstream" psychology seems unable to deal with the facts of conceptualization, learning, creativity, awareness, or the seldom referenced, but massive, data accumulated over a century of experimental psychology (the work on problem solving and problem formulation, for instance, which is summarized in Pask (1977c)). Finally, there are reasons to do with scientific endeavor in the psychological/social field that are, to a large extent, neglected by the "mainstream" movements, though not, for example, by epistomologically based psychologies (Piaget, Luria, Vygotsky), or similarly minded sociologies.

It is desirable, for example, to have a *sharp valued* type of observation, peculiar to the psychological and social disciplines, which may be obtained by locating agreements over an understanding of topics (or a sharing of stable concepts) through a conversational command and question language, L. The sharp valued observations may surely be surrounded by fuzzy, probabilistic, or partially indeterminate observations; for example, the agreements reached between participants over personal constructs (Kelly, 1955; Bannister and Mair, 1968; Bannister, 1971; Fransella and Bannister, 1977) obtained by exchange grid methods (as used by Thomas, 1970, 1971; Glanville, 1978; or Abel, 1977), which are agreements over descriptions. It is also possible to gain something from the more easily observed, though far less informative, responses of behavioral studies provided that there is an underlying sharp valued *psychological* observation to which these measurements refer (notice the qualifier "psychological"; it is easy enough to record a "sharp valued *response event*"; whether it has any relevance to the subject, or to psychology in general, is a different matter).

In this paper conversation theory is justified on somewhat different grounds; namely, that it is a proper theory of consciousness, as a result of which its epistemology is able to embrace analogy, characterization, and the stories, or parables or allegories that characters enact.

1 THE ARGUMENT

In order to express L agreements over understandings between participants A, B, ... it is necessary to adopt a cybernetic or general systemic approach. Further, the classical forms of cybernetics and general system theory must be replaced by nonclassical forms, due to Goguen (1975), Maturana (1975), Varela (1975), and Von Foerster (1976), or independently, to Andreka, Gergely, and Nemeti (1975) or (again, independently) to Braten (1977) and

Herbst (1976), or (again, independently) to Glanville (1976), to Gaines (1977), Bykhovsky (1974), and others.

1.1 Organizational Closure as a Stability

All of these (mostly independent) formulations replace the classical canons of deterministic or probabilistic stability by organizational closure of a *process* that is productive and, incidentally, also *reproduces* the medium, or processor, in which it is executed; most critically, by establishing, or maintaining the distinctions (in biology, the bounding surfaces) required for its coherent execution.

1.2 Informationally Open, Organizationally Closed, Processes

Another distinctive feature of the nonclassical formulations is that they are generally reflective and relativistic in character, because *organizationally closed* systems are often *informationally open.* This point is especially germane to conversation theory, where stable (as a result of organizational closure) units are participants in a conversation that involves information transfer (for example, between A and B) implicating process sharing.

1.3 Fundamental Information

The word *information* is used in its most fundamental sense (Petri, 1964; Holt, 1972) to mean either "emergence of local synochronicity between otherwise asynchronous systems," or (equisignificantly) "emergence of dependency between otherwise independent systems." Conversely, essential synochrocities in the ongoing process make it necessary to predicate, or to compute, distinctions that render parts of the medium independent; these distinctions being needed if the process is to take place. This usage of "information" is distinct from the "information" attached to various information theories (Ashby, 1956; Shannon and Weaver, 1949) or others, such as those of Gabor and McKay, or Bar Hillel (the most elegant general discussion is still in Cherry's (1957) book, updated by Glushkov, 1966). The measures obtained *do*, of course, *estimate* the "fundamental" information transfer, but in different ways.

1.4 The Conscious State

It will be argued that fundamental information transfer between participants A and B *is* their consciousness (A's consciousness with B of whatever they

discuss), the emerging synchronicity, or dependency, being a correlate of coherent process sharing, or agreement, between the participants. The *degree* of consciousness is their doubt, which is many-faceted (doubt about focus of attention, doubt about outcomes, doubt about methods), but it may be quantified by fairly sophisticated confidence estimation techniques. The *content* of consciousness is whatever processes are shared by the participants.

1.5 Organization of a Conscious Process

A process is potentially conscious if it is organizationally closed, informationally open, and if information is transferred across distinctions that are computed *as required to permit the execution* of the process. When the distinctions are so placed that the content of this transfer appears as a series of L statements between participants, then it *is* a conscious process. In the absence of that condition, it may still be legitimate to speak of awareness and possibly *thought*; "consciousness" is reserved, as McCulloch (1965) insists, for a situation in which participants are conscious, *with* one another, *of* something. But a liberal interpretation of "participant" is permissible; for example, one person may be conscious with himself, insofar as he entertains several, identifiable, "perspectives."

2 THE PARTICIPANTS AND THEIR DIALOGUE

Although the participants A, B, . . . are defined as "organizationally closed and informationally open systems," A, B, . . . are intuitively *seen* as people with personal integrity and brains they call their own. If so, A and B engage in conversation about something (call it T), which is a topic they commonly name, in L, and can ostend, or point at; quite possibly T is one of *them* (T = A, or T = B). Their dialogue is personally addressed and consists, for the most part, in commands (or weaker forms of statement expressing intent, desire, etc.), or questions (interrogations, inquiries), together with whatever amounts to obeying a command or answering a question.

2.1 Some L Transactions

Notice that all L transactions are personally addressed (to A, to B) and that a question is simply a command that calls for (and may or may not be obeyed by) an intellectual rather than a concrete series of actions. Thus, if A asks B "how he does T," or "what he means by T," then B will generally offer an

explanation; if A asks B "why did you explain T that way?", then B will generally explain or "justify" his explanation, which, to avoid the inconvenient though legitimate usage, "explanation of explanation" is called a derivation of T; if A asks B "how else he explains T," then he usually receives another explanation; if A asks B to describe T, then B gives values of predicates (which may be other topics) that characterize T; in reply to "what is T," examples are cited, and in reply to "which of these is T," the reply is a selection. This by no means exhausts the potentialities of L: for example, A may ask what B believes A thinks about T, or (substituting T by A and B) what B believes, or what B believes that A believes.

These L-transactions are interpreted actively. Very many L-transactions (perhaps all of them) represent processes. Terms such as "an L-expression" or "an L-statement" can be misleading because they suggest the stuff of a textbook, and not the essentially dynamic characteristics of real (in contrast to formal) language usage.

In particular, an explanation is a *process.* Quite often and quite usefully, a "mathematical proof" is cited as a peculiarly pure kind of explanation, which it is. However, the meaning, in conversation theory, is the "exposition of a proof" (starting with a given set of axioms and rules delineate a sequence, ending in the theorem to be proved). This is an activity; in conversation theory, at any rate, a "proof" does not mean "the proof statement, as written down in a textbook." Moreover, explanations are by no means limited to "mathematical proofs"; they are simply explanations of how or why some circumstance pertains or some action is taken.

Quite distinctly, A might execute a process, represented by any one of his explanations, in his brain as an "internal behavior," which could (depending upon the process concerned) be exteriorized as an "external behavior" or could act as A's image of T, or both. Similarly, B can execute a process and produce an "internal behavior," which may or may not give rise to "external behavior" or to B's image of T or both. The circumstances under which process execution does and does not give rise to imaging are discussed in Section 2.3.

With "explanations" firmly established as processes rather than "strings of symbols," the concepts entertained by the participants will be viewed (and later defined) as certain bundles, or clusters, of processes that "do the same thing" or, more generally, "regulate matters so that a relation exists."

Derivations ("explanations of explanations") are also processes; they are, in fact, processes for producing and reproducing the processes that make up a concept. Further, with only technical variations, the same kind of dynamism

can be attributed to all L transactions, for example questions, expressions of desire, and the like.

There is nothing outrageously novel about this position. The reader is asked to take the commonsensical view that units of reality *are* processes, seriously, that is all. The position does, however, contrast with the familiar formalisms in which static "elements" are postulated; from these, by devious and slightly arbitrary routes, different formalists construct *events*, from these, by dint of quite tortuous arguments, different formalists arrive at more or less restricted images of a *process.*

2.2 Agreement over an Understanding of T

Agreement over an understanding of T (in a conversation between participants A and B) is recognizable in L dialogue and is the event picked out by a sharp valued observation of this dialogue.

Stated loosely, agreement over an understanding means that A's productive and reproduced (i.e., stable) concept of T has a part that is *coherent* with (or, to use a general term introduced by Erhardt, is *aligned* with) B's productive and reproduced (i.e., stable) concept of T, and vice versa (Erhardt and Gioscia, 1977).

Using natural language for L, participant A offers at least one explanation of T, which B accepts, can use to produce B's image, T_B, of T and can reproduce it to form part of B's concept of T (denoted $Con_B(T)$, as a shorthand). To satisfy this condition, for some unfamiliar topic, A needs, in general, to indicate to B how he *derived* the explanation of T that A accepts; as a guideline to a method of reproducing, or reconstructing, this explanation.

Similarly, participant B offers at least one explanation of T, which A accepts, can use to produce A's image, T_A, of T and can reproduce, to form part of A's concept of T (designated $Con_A(T)$, as a shorthand). In general, B needs to furnish A with a means for *deriving* the explanation that A accepts, as a guideline for reproducing or reconstructing this explanation.

By hypothesis stated already, A's concept of T is productive and reproduced; also, B's concept of T is productive and reproduced. Agreement over an understanding implies that some of the explanatory processes (at least one) that make up $Con_A(T)$ also belong to and are reproduced in $Con_B(T)$; vice versa, that some of the explanatory processes (at least one of them) that make up $Con_B(T)$, also belong to, and are reproduced in, $Con_A(T)$. In other words, the initially independent participants, A and B, in this conversation share a common concept, which, being productive and reproduced in its own

right (as a result of the conditions for agreement over an understanding reached between A and B), is also a stable (organizationally closed) process.

2.3 Conversational Topics

Let us call T a "topic" (this has an intuitive meaning only, at this stage; later, it is refined and discussed). Similarly, let us call the concept that is common to A and B the concept of a topic T^* which is "less than or corresponding to T"; tentatively expressed by "$\geqslant$" in

$$T \geqslant T^*$$

Consider A's concept of T and B's concept of T; namely, $Con_A(T)$ and $Con_B(T)$. From Section 2.1 concepts are "bundles" or "clusters" of processes.

Further, in Section 2.2, the idea of an "internal behavior" was mooted. This internal behavior may (depending upon $Con_A(T)$) be manifest as A's image. It is produced upon executing $Con_A(T)$ meaning the execution of any or all of the processes making up $Con_A(T)$. This fact is expressed by

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

where "Ex" stands for "execution of," and "$\Rightarrow$" stands for "is produced by."

Symmetrically, for the participant B

$$Ex\,(Con_B(T)) \Rightarrow T_B$$

The stable concept shared as a result of understanding by A and B is a common (and stable) part of $Con_A(T)$ and $Con_B(T)$ so that

$$Ex\,(Con_A(T)) \Rightarrow T_A \geqslant T^* \leqslant T_B \Leftarrow (Con_B(T))\,Ex$$

This symbolism is not able (or intended) to capture all the requirements for an agreement over an *understanding* (it *is* certainly *one* of several, necessarily distinct ways of expressing an agreed *description*). The outstanding conditions are to do with the productivity and reproduction of the common concept, agreed as an understanding, without which the common concept would not be a stable (organizationally closed) process. For one thing, explanations that represent concepts must be elicited; for another, some common

process must be shared; finally, stability must be evidenced by derivation. These matters are taken up in Section 2.5. Here, we comment only upon a shared process and the entity T^*, produced as a result of executing the concept of T^*, shared by A and B.

Alone these lines, if $Con_A(T)$ and $Con_B(T)$ *really* are stable and if the common concept *really is* stable then there are subprocesses in $Con_A(T)$, designated $Con_A(T^*)$, such that, using "$\subseteq$" for "inclusion or equality," as usual.

$$Ex\,(Con_A(T^*)) \Rightarrow T_A^* \subseteq T_A \Leftarrow ((Con_A(T))\,Ex$$

Further, symmetrically for participant B, there are subprocesses in $Con_B(T)$ designated $Con_B(T^*)$ such that

$$Ex\,(Con_B(T^*)) \Rightarrow T_B^* \subseteq T_B \Leftarrow (Con_B(T))\,Ex$$

Whatever else, A is not B; nor is $Con_A(T)$ the same as $Con_B(T)$. Hence, it is not permissible or sensible to write "$T_A^* = T_B^* = T^*$." However, if the sign "$\Leftrightarrow$" stands for an isomorphism, it is possible that

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

or, in general, that there is a T preserving morphism, or matching, of different entities, the meaning now assigned to "$\geqslant$" or "$\leqslant$"

$$T_A \supseteq T_A^* \geqslant T^* \leqslant T_B^* \subseteq T_B$$

The "topic," T, remains elusive. The plain fact is that T, as a topic, is the coherent execution of stable concepts (stable processes).* The name, "T," of a topic can be formalized but never fixed; formally, it denotes union, over an infinite class of conversations (between arbitrary participants including A and B), of the T^* of all of them.

From a linquistic perspective "T" is the noun like part of a stable process; it is also the set of adjectival descriptions of an indeterminate (the union of the conjunctions of descriptor values, where the descriptors are generated

*In Von Foerster's (1978) sense, topic names consist in the eigenvalues of a concept, which is a stable concept insofar as it is an eigenoperator. The eigenvalues characterize its indefinite iteration and (given stability), the iteration becomes a recursion.

like personal constructs by executing other concepts). One is tempted to think of "T" as merely "that which T^* becomes in the limit," as the end point of an operation (like transitive closure) which is iterated indefinitely.

The implied convergence is acceptable *if* and *only* if, A and B are fixed, and do, in fact, converse. But convergence cannot be guaranteed. Nouns are not realities, except in relation to a culture or a system of belief; even with this qualification, the invariance of nouns is unimpressive. For example, Eskimo conversants have many nouns meaning *snow*, but in our culture there is usually only one; the novice in a monastery has a myriad of nouns for naming "meditation," and so on. As to invariance; when we go to the Alps, snow becomes many faceted, and there is a tendency nowadays to be more discriminating about states of mind.

2.4 Difficulties in the Interpretation of Natural Language Transactions

In Section 2.2 it was possible to give an intuitively plausible account of the conditions to be satisfied in reaching an agreement over an understanding. So far as I know, there is nothing wrong in principle with this account, and it seems to tally with everyday experience.

The question is *who* says what *does* count as being a natural language explanation or derivation; the commonly voiced problem of disambiguating natural language utterances, which is encountered in any field where natural language is observed; in discourse analysis, for example, or automatic translation.

So far as the participants are concerned, this does not greatly matter. They (A and B) are satisfied and it is *they*, after all, who *reach* agreement; it is *their* criteria that count. Moreover, I am inclined to the view that this, in general, *is* sufficient, for a reason mentioned, but not perhaps stressed enough in Section 2.2.

The truth value of an agreement, in whatever language is employed, is a coherence truth (indicating the accord or alignment of A and B). In logic, the notion of coherence truth has been developed, recently, by Rescher (1973), though it has a long history.

Rescher's formulation deals with propositions (he notes that it is easy to recast the thesis in terms of a predicate calculus). The general idea is as follows.

Suppose there are several "observers" of data, all of whom subscribe to a body of hypotheses, or a tentative "theory." These "observers" have, let us

say, the same criteria of veridiciality or factual truth. The question arises of which, possibly contradictory, bits of factual evidence will gain acceptance. A "coherence truth" `value` does not *neglect* the veridiciality criteria employed when examining a datum for truth candidacy, but it *does* take into account also the extent to which data fit into the existing set of hypotheses: whether or not the evidence is systemically compatible with an already accepted and well tried body of hypotheses (in Rescher's formulation as a further proposition, to be added to an existing set of propositions). Unlike Rescher, it is necessary to countenance participants, other than scientists, inspecting evidence and to admit veridiciality criteria of different kinds (artistic or commonsensical) as neither better nor worse than the canons of science. But given some criteria of acceptance (whatever they are), the coherence and fittingness of a state of affairs is an issue to do with the language in which the participants engage in conversation with each other.

Two amendments to Rescher's formulation are required in order to obtain a coherence truth appropriate to the present scheme.

It is first of all necessary to import the process orientation, introduced in Section 2.1. The idea of a proposition logically "fitting into a set of propositions," must be replaced by the equivalent dynamic form; a "*process* (or a propositional statement being *made*) fitting into a set of processes, so that execution is possible." Of the two amendments, this one is of largely technical consequence (the difficulties encountered in formalizing a process are indisputable but largely due to a historical quirk in the development of formal reasoning).

Next, it is necessary to take the notion of predication or distinction seriously, and to import a logic of distinctions (for example, Spenser Brown's, 1969). *A fortiori*, the participants A and B are distinct and may have different criteria of veridiciality or factuality. An agreement over an understanding having a coherence truth value is to be interpreted as a local synchronization of otherwise asynchronous processes (within which the processes could not be coherently executed) or, equisignificantly, the local appearance of dependency between otherwise independent entities. To balance dependency, there must be a mechanism for securing independence; a mechanism of distinction; the logical concomitant of which is a many *sorted* logic (i.e., using "universe of interpretation" in its usual sense, the interpretation or semantic of L involves many *sorts* of "universe," not just one universe).

One candidate for a many sorted logic is the intensional logic of Montague (1976), the syntax of which has a many-sorted semantic-interpretation. This scheme has been proposed by Andreka and discussed with Gergely,

Nemeti, Szotts, and others in November of 1977 at Budapest. The suggestion is certainly attractive. This group are nonclassical (action valued) model theorists, currently, among other tasks, undertaking a formalization of conversation theory. Between us, we could see no fundamental difficulty in replacing the static (sets-of-elements) Montague universes by processes (as required in the first amendment), or even quite unconventional processors.

The difficulty, which may be remedied, appears in the context of one of Montague's essays where he achieves a translation of a subset of syntactic expressions of the English language into a Montague syntax and provides, thereby, an interpretation in the many sorted Montague semantics. It turned out in discussion that a metaphor in English, denoting an analogy, cannot be so translated (the technical reason is simply that Montague's translation requires the English expressions to be represented in terms of a categorical grammar, which is algorithmically transformed into the syntactic expressions of a Montague logic; this step has the effect of rendering analogies as similitudes, i.e., whereas an analogy always involves both a similarity and a distinction, the similitude does not incorporate the crucial distinction).

It looks as though an alternative translation scheme that respects analogies (denoted by metaphors) may work. However, the importance of this innovation can scarcely be overemphasized. Not only is analogy, as such, critical in the development of a conversation theory; it is also true, as later, that analogy is the "most static" or "most assertoric" representative of all the questions, intents, etc., indicated in Section 2.1.

Supposing that more serious objections to natural language are met by the expedients under discussion, one hurdle still remains. Conjure as we may, natural language statements are very often hazy. For ordinary purposes I am not disquieted by this fact, and formally *this* kind of "haziness ambiguity" is readily accommodated by "Fuzzy System theory, and Fuzzy Set theory" (Goguen, 1969; Zadeh, 1974, 1976). There is, however, a practical problem insofar as the participants in a conversation are required to interact through a mechanical interface (CASTE or THOUGHTSTICKER, Pask et al. 1973), which must, in some sense, interpret their dialogue.

2.5 Other Types of Participant and the Minimal Processes

So far, A and B have been regarded as people, though they are defined as stable processes. The definition permits many other interpretations.

For example, one or both of A and B may represent groups or cultures or social institutions, executed, qua process, in many brains, over which the

group beliefs, the cultural ethos, or the norms of a social institution are distributed.

Equally, A and B may represent coherent mental organizations in one brain (different *perspectives* of one person) learning alone, thinking, or theorizing. If so, the "internal" conversation, between A and B (about a thesis, for example, or a design, may still be exteriorized for inspection, insofar as it takes place in language L.

Conversation theory is thus widely applicable and uncommitted to any one interpretation. Participants may be perspectives, people, cultures, societies, schools of thought, or social institutions.

In the following three sections one user with perspectives A and B (or quite commonly a group of users, but in any case several perspectives A, B, . . .) converse through a computer regulated interface, using a special nonverbal form of language L.

2.6 Other Conversational Languages

It is possible to maintain dialogue *through* (to be emphasized, not *with*) mechanical interfaces like CASTE and THOUGHTSTICKER using a language, L, which is nonverbal. The existing implementation uses several modalities for bearing L symbols (graphic displays, some alpha numeric displays, indicators laid out on a board, touch sensors, function keyboards, standard keyboards, position sensors, and the like).

The nonverbal conversational language L has the properties outlined in Section 2.4, but the machinery can interpret definite transactions when they are made. Fuzzy transactions (Zadeh, 1976, 1977) are not excluded, and, in certain conditions, are mandatory.

An entailment mesh, together with mechanizable operations (notably pruning or unfoldment, selective pruning, condensation, expansion, and unzipping), is a static inscription guaranteed to represent *stable* concepts or agreements over an understanding, the basic transactions between participants. (Pask 1975a, 1976c, 1977a).

The entailment mesh is represented by a directed and marked graph (which is usually conceived as the exposition of a thesis, plan, or design) in which the nodes stand for topics and the directed arcs stand for derivations of topics.

In one variant (Section 2.7) of an L conversational system, each node has a data pointer (not an arc in the graph) to a working model, and another data pointer to a description scheme. In the other variant (Section 2.8) there is

only one pointer at a node. The schemes are equivalent, since the mesh operations just noted provided that the rules of L usage, proper to the schemé, are obeyed. These rules are simple to appreciate and are enforced by a computer regulated part of the interface.

The rules common to the schemes in Section 2.7 and Section 2.8 are as follows.

(a) Topics are of two types: topics (simpliciter) denoted "○," analogical topics, denoted "◇."

(b) No topic may stand on its own. Thus it is not legitimate to write T without something else (two or more other topics from which T may be derived, say P and Q; as the other topics). For example, in a theory of geometry, T is "circle" and is derived from P = "plane surface" and Q = "rotation of a line of any length but any fixed origin." In electronic design, "regulated power supply" is derived from "power supply" and "a suitable regulator, with a reference potential."

(c) If T, unless analogical, is derived from P and Q then P may be derived from T and Q; similarly, Q may be derived from T and P together. This means "given an explanation of T is derived from an explanation of P and an explanation of Q, then an explanation of P may be derived from. . . ."

(d) Any topic may have any number of derivations (for example, T may be derived from P and Q, or R and S or both). This, as in (c) above, is a shorthand for "If T is derived from an explanation of. . . ."

(e) Any analogical topic relates several other topics. Thus, T, an analogy, relates other topics F and G. For example, T is "linear oscillator," relating F = "linear mechanical oscillator" and G = "linear electrical oscillator." In design, one circuit is analogous to another circuit and both are analogous to a process they simulate.

Any analogical topic must be supported by either a similarity (*Simi*) and a distinction (*Dist*), or by the derivation of a similarity and a distinction. For example, in the first case cited, *Simi* of T is a first order differential equation, *Dist* is a distinction between electrical and mechanical universes. If these conditions are not satisfied, and an analogical topic is asserted, the system handling L transactions assumes that the similarity is isomorphism "⇔," and the distinction is any conceivable method of securing the independence of F and G (that is, "any distinction" shown as *Dist* ∅). It should be stressed that analogies are *not* confined to strict mathematical relations and fuzzy or even qualitative analogies (for example, between social institutions or legal codes) are as common. In any case (precise or not), there are infinitely many ways of computing *Dist* that *work*, as well as infinitely many that *do not*.

(f) The mesh that is asserted is of order 0. It may be condensed to a mesh at order 1, or, in general, n. Any mesh of order n may be expanded to a mesh of order $n-1$, or, ultimately, 0.

To refine this slightly, consider the cyclic entailment mesh (cyclic because of rules (c) and (d)) and notice that it can be *pruned* or *unfolded* into a hierarchical form under any (one or more) perspective of which there are as many as there are topics in the *entailment mesh*. In fact, any action (of learning or doing) necessarily imposes a hierarchical ordering from the perspective adopted to learn or behave, the possibilities being delineated in an *entailment structure*. The class of all prunings is the *pruning field*.

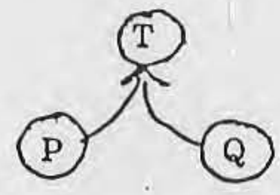
Condensation carries structures in the *pruning field*, of order n, into topic nodes in a mesh of order $n+1$, which may in turn be related by derivations so that the mesh evolves.

The converse operation (of retrieving the original at order n, from each topic at order $n+1$) is unique, if derivations have not been added at order $n+1$, and is called *expansion*. If the order $n+1$ mesh has been modified there are specific, but no longer unique, expansions.

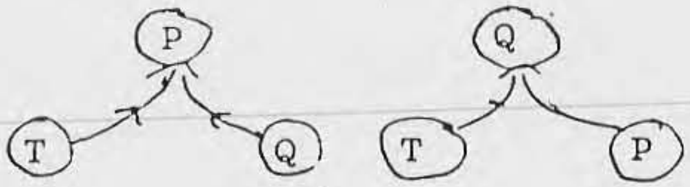
Operations of this kind are carried out automatically by THOUGHTSTICKER and CASTE, the L handling computer systems.

All static inscriptions are checked before they are instated at the mechanical interface, and their consequences are displayed; for example, that if T is derived from P and Q, then P is derivable from T and Q; similarly, Q is derivable from T and P. Though seemingly trivial when the entailment mesh is small, these consequences are fairly subtle when it is large. Also, the overgeneralizations, such as the assumption that *Simi* is *isomorphism*, have rather far-reaching consequences (for example, whatever F and G are derived from will be isomorphically related). For instance, in the first case cited, *mass* is isomorphic to *inductance*, *friction* is isomorphic to *resistance*, and *elasticity* is isomorphic to the *capacity*, in the electrical universe.

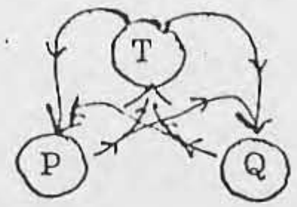
Since "T" is disallowed, from "Rule (b), the minimal logical structure for a topic, simpliciter, is



from (b). Further, this means also that



So that the instatement of T is

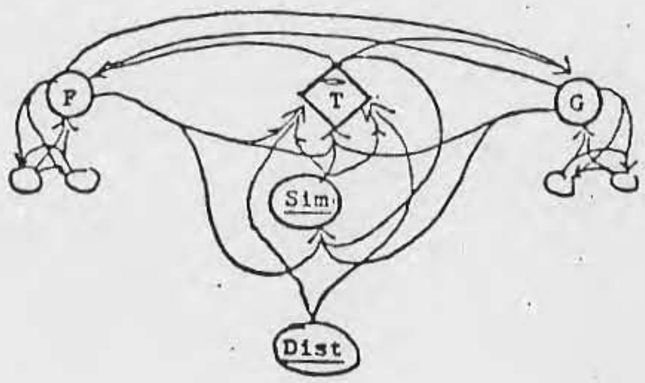


a cyclic organization.

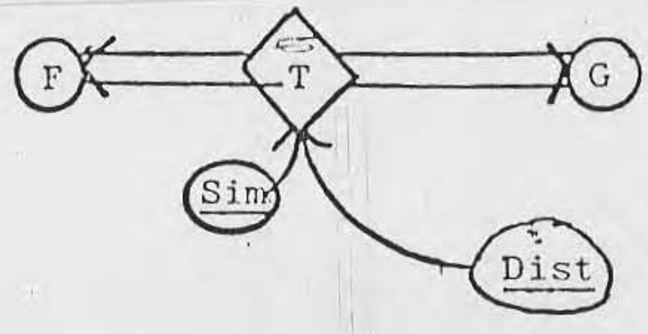
Since all participants may think differently, no commitment is attached to the derivation arcs provided the participants are able, by any productive and reproductive operations at their disposal, to retain the specificity implied by this cyclic picture.

These comments apply to any order of condensation (Rule (f)). The expansion of a condensation is unique if no L statements involving it take place at an order greater than 0. If such L statements are made, expansions exist but are not unique.

By the same token, the minimal inscription for an analogical topic $\dot{T}$ relating F and G coexisting in distinct and a priori independent universes as derivations and specifying between them, a distinction is a complex and no longer entirely closed system. Thus, if F and G are associated by T, the form below suffices (any *Simi* can be replaced by a *derivation* of *Simi*, from *other* topics, as desired).



For convenience, a shorthand notation is used. This is as follows:



2.7 The Model as an Explanation Embodiment

Let us turn to the model making interpretation in which "verbal explanations" are replaced by "working models."

(g) All topics must be associated (either at once, or at any subsequent moment, before the entailment mesh is finally accepted for instatement, as the static inscription of a logical L transaction) with working models; programs complied and capable of independent execution in one or more "modeling facilities," or processors external to the participants. (Both A and B must build distinct working models in independent processors). One data link (Section 2.6) attaches the node of each topic to a "working model."

One of the most familiar "working models" is a program written in LOGO (Pappert, 1970). Feurtzig and Pappert (1969), Howe and O'Shea (1976), compiled, or interpreted for execution, in an external processor (computing machine, equipped with a "turtle," or a display-equivalent "turtle"). For example, instead of providing a verbal explanation of T = "Circle," participant A is required to write a LOGO program which, upon execution makes the turtle, or the turtle display, describe a circular figure and to allow for parameter assignments that set up an arbitrary center and diameter. Similarly, there are programs that satisfactorily simulate P = "plane surface," (say as a repertoire of motions of the turtle) and Q = "radial inscription" (to delineate and rotate a radius). These programs are nonverbal explanations in the following sense.

If $Con_A(T)$ is stable, it consists (as will be discussed in Section 3) in a cluster of coherently executable procedures (alias, programs interpreted and executed in A's brain), any one of which is representative of $Con_A(T)$. The program listings could be elicited as verbal explanations acceptable to another person (B), but if both A and B know LOGO, then a LOGO listing is

equivalent, provided it can be interpreted and executed in the external computer, independently.

To satisfy the independence of A and B, each participant must have a distinct LOGO processor, so that their programs and their attempts to write them do not interfere, and so that possibly different programs can be compared and contrasted after A and B have modified the listing to their satisfaction.

Of course, LOGO is not the only transparent programming language, SMALLTALK (Winograd and Kaye) is another. We, in fact, use analogue/hybrid simulators and computer traced devices that are specific to broad fields of subject matter.

The working model for an analogical topic, $\dot{T}$, is a little more complex. A and B must both have at least two (in general, more than two) external computers so that they can each compare and contrast their own working models for F and G as a result of which they can agree about the similarity and difference between F and G (as made by A) and of F and G′(as made by B). Hence, a minimum of 4 external computers is needed (a minimum of 2 for participant A, and 2 for participant B) in order to obtain agreement over the explanations of an analogical topic. Moreover, these computers (which, as given, are simply independent) must be cogently distinguished (for example, so that one (X_A) is a universe for accommodating the working model of a mechanical oscillator and the other is a universe, Y_A (say), for accommodating the working model of an electrical oscillator). Similar comments apply to participant B excepting that his distinction X_B/Y_B (though usually not at all identical) shall be compatible with the A distinctions.

(h) The other data link (Section 2.6) connects the node of each topic to a description scheme whereby the node can be identified or named (users may give arbitrary or temporary names to topics but the real topic names are conjuncts of descriptor values that uniquely identify each node in the entailment mesh).

Descriptors are elicited in the manner of Kelly's personal constructs (Introduction), over topics in the entailment mesh, which are the objects being described. The algorithm used for this purpose (by CASTE or THOUGHTSTICKER) is selective insofar as it centers initially upon analogical topics, requiring one or more descriptors (with values of "+" = has, "–" = has not, and "*" = is irrelevant) having values that differ upon the topics related by the analogy but, insofar as the analogical topic is concerned, the value of "*" = irrelevant. The descriptor names, thus elicited, are entered in place of *Dist* in the analogy; thus if D is a descriptor with value "+" on F,

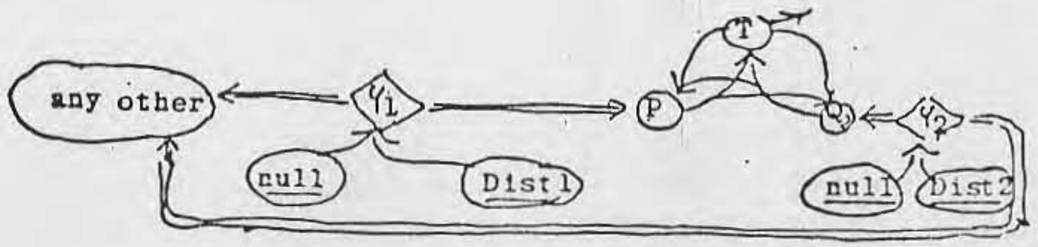
"–" on G, the value "*" is assigned to $\dot{T}$, and the name "D" is entered in *Dist* of $\dot{T}$.

Since several orders of condensation of a mesh may coexist, the algorithm starts at the highest order and requires (for each order of mesh) that conjuncts of descriptor values uniquely identify each topic. This result *may* be achieved by the analogy selecting method above; if *not*, then the process is continued until this condition *is*, satisfied.

Modifications of the method include the use of many valued descriptors and, for several users, a type of exchange grid (Introduction) technique to reach agreement over a description (or set of descriptors and common value assignments to each).

2.8 Eliminating the Requirement of Explicit Working Models

Under certain circumstances, it is neither necessary nor appropriate to call for the explicit construction of a working model attached to any logically instated topic and an alternative technique is adopted. This technique relies upon the idea that condensation and the converse operation of expansion can set a limit to the proliferation of a mesh provided that there is a reserved analogy type, γ_i, called "any other." Perhaps the notion is most easily exhibited in the context of theory building or thesis exposition (say a thesis on genetics or physical chemistry). The fact is either subject matter is somehow related to any other. Subject matter is dissected out from knowledge in general, as a particular thesis or an entire discipline, by the distinctions that underlie a degenerate analogy (the reserved, γ_i, or "any other" analogy), in which the similarity component exists but is underspecified. For example, in



γ_1 and γ_2 are degenerate (*Sim* = *Null* cannot be derived for γ_1 or γ_2 or any γ_i).

Consider an ordinary topic, T, and the caliber of the working model that would, in Section 2.7, be attached to it. Since T cannot legally exist on its own, it forms part of a mesh. This mesh can be pruned under all of its topics

to produce a pruning field. Each element in the pruning field of the original mesh (say, of order 0) can be condensed to one topic in a mesh of order +1 (or, in general, of order n). Given a mesh of order +1 (or $+n$) it can be expanded (uniquely or not) to retrieve at least one element in the pruning field of order 0 and thus, over all topics, a mesh of order 0.

Consider a topic T at order 0. What does it represent? It may either be conceived as representing its derivational connection at order 0 and the working model attached to topic T, or (just as legitimately) as its derivational connection at order 0, and the condensation of a mesh of order -1 (or $-m$).

We cannot algorithmically expand topic T if 0 is the lowest order mesh in the system. However, in place of a working model, the user or group of users can be impelled to "unzip" topic T; that is, to say what T is derived from.*

How far can this operation (which enlarges the order 0 mesh) continue? It may go on until the user (or group of users) is unable to furnish a derivation because (to him) the topic is elementary or indivisible (not to be equated with more or less complex, or, in any absolute sense, primitive). Let us call such maximally "unzipped" topics *indivisible* (for A or for B or for A and B in conversation about a joint thesis).

Each *indivisible* topic is one term of an "any other" analogy. On description of the mesh the *Dist* of the "any other" analogy will be filled by some descriptor that discriminates A's or B's thesis or the A and B thesis from the rest of knowledge. In the last illustration, P and Q are indivisible topics (T could be, but has an outgoing arc connecting it to some other topic in the mesh).

Some of the indivisible topics represent (in computer-science language) "primitive operations"; some indivisible topics (again in computer-science language) represent primitive predicates. The *Dist* terms in all of the nondegenerate analogies (those that are not γ_i or "any other" analogies) represent distinctions between independent universes) in the thesis (so that, unlike computation in general, there may be many sorts (Section 2.4) of primitive operation, and many sorts of primitive predicate). The "any other" analogies relate the thesis to an (arbitrarily) independent, and infinitely large, universe of knowledge (commonly the disciplinary compartments of academic subject matter are distinguished on grounds such as these, in fact multifarious, distinctions).

There is a theorem, due to Steltzer (1977), that any genuine *example* is

* Unzipping is defined in Pask, 1975a, Pask, Scott & Kallikourdis 1975 as adding derivations to a mesh.

an *analogy*. In this sense, either "physics" or "chemistry" are *examples* of "science," and "science" is an *example* of knowledge.

Operationally, the requirement imposed in Section 2.6(g) for assigning a working model to each topic, may be waived if we replace it by:

(g*) For each topic having no working model "unzip" the topic until the process is bounded by "any other" analogies that have indivisible topics as one related component and assign primitive operations and primitive predicates, as `required`.

Descriptor value elicitation proceeds as in Section 2.6(h), except that:

(h*) In addition to operation (h), elicit descriptors with value "+" on each "indivisible" topic and value "+" on all topics in that part of the mesh (or the entire mesh if all topics are of the same sort in the sense of Section 2.4) that is of the same sort as the indivisible topic in question (that is not rendered independent by the *Dist* of a nondegenerate analogical topic). Enter the descriptor names in the *Dist* components of each γ_i, or "any other" analogical topic.

3 MINIMAL ORGANIZATIONALLY CLOSED PROCESSES

From Section 2.2 and 2.3 the minimal stable (organizationally closed) process that exists is called a *stable concept*, using the term "concept" as a synonym for "skill" (intellectual skill, if you like), the execution of which gives rise to a description (image, imagination) or a behavior, or both of them. The notion of minimality should be examined carefully. My concept of "society," for example, may be larger than any concept I have of "myself." Hence, the minimality notion is not "minimal size." Rather, it is an operational minimality, which refers to the least organizationally closed but informationally open process, which can be dissected out arbitrarily from a nexus of interacting processes and be said to have an autonomy or integrity of its own.

3.1 Concepts of Participants

A concept is denoted *Con*. In particular, $Con_A(T)$ is A's concept of T, where T is as yet unspecified.

$Con_A(T)$ is defined in terms of procedures ($Proc_A$) that are open to execution as processes, so that a procedure is like a working model, built in the medium of a brain. Consequently, it is not *just* a program (series of syntactically valid instructions), but a compiled or interpreted program. If *Inter* stands for the interpretation of a program, and if *Prog* stands for the

instructions that are interpreted for execution in this medium, then if "⟨" and "⟩" denote ordered sets, $Proc_A$ is an ordered pair.

$$Proc_A \triangleq \langle Prog_A, Inter_A \rangle$$

(It is nonsense to say "*Ex* (*Prog*)," meaning "Execute *Prog*" with no processor implied, as it would be in standard computer science; one *can* say *Ex* ($Proc_A$)).

All of these terms may be qualified, to indicate programs that do particular things (*Prog* p, *Prog* q . . .), or do them in different ways (*Prog* 1p, *Prog* 2p . . . *Prog* 1q, *Prog* 2q . . .) and they may be interpreted in different processors or quasi independent (or independent) parts X, Y, . . . of any one processor (*Inter* X, *Inter* Y, . . .).

It is important to note that $Proc_A$ is named $Proc_A$i insofar as Ex ($Proc_A$i) ⇒ i_A. If i, j, k, l, are different indices, and if

$Proc_A$ i = ⟨*Prog* p, *Inter* X⟩

$Proc_A$ j = ⟨*Prog* q, *Inter* X⟩

$Proc_A$ k = ⟨*Prog* p, *Inter* Y⟩

$Proc_A$ l = ⟨*Prog* q, *Inter* Y⟩

these are all, necessarily, distinct, if they exist (they may not exist if, for example, *Prog* p with *Inter* Y is *not* an executable compilation, though *Prog* p with *Inter* X, *is*).

In order to specify a concept, as conveniently as possible, and using a concise and transparent notation the following conventions are adopted as standard forms. If u, v, stand for *Procs* as above,then

3.1.1 Conventions.

⟨u,v⟩	The ordered pair (or *n*-tuple) u, v, (as before)
{u,v}	An unordered set of u, v.
$\{u_r\}$	An unordered set of u_r, (or v_r) r = 1, 2, . . . in which processes may conflict in execution
[u,v]	The compilation of programs such that they are executed in parallel. For example, u,v may be compiled in independent processors, or interlaced, with interrupt, in one.

$[v_r]$	A set of parallel processes u_r, or v_r, r = 1, 2, . . .
$\langle\{u_r\}, [v_r]\rangle$	A concurrent set of processes of which there is a subset of parallel-executed processes and some (one or more) conflicting process

3.1.2 Principle 1 (Concept). In certain media or processors, recompilation takes place so that $\{u_r\} \rightarrow \langle\{u_r\}, [v_r]\rangle \rightarrow [v_r]$. There is a *tendency* for the execution of process to *become* coherent.

3.1.3 Principle 2 (Media). Any participant, A, B, . . ., is a process involving such a media. Brains for example, can act in this manner, any concept belongs to one or more of A, B, . . . (a very liberal requirement in view of Section 2). *Con* is necessarily subscripted as Con_A or Con_B (in general, some value of a variable Z = A, B, . . .). It is essential to recognize that Z designates processes (neither processors, such as brains, nor syntactic entities such as programs). If "⇔" stands for isomorphism, it is conceivable that $Con_A(T) \Leftrightarrow Con_B(T)$ for any T, but the expression "$Con_A(T) = Con_B(T)$" is meaningless.

3.1.4 Definition. For any value of Z (such as A)

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

and no other thing is a concept.

Of these, only the last $[Proc_A]$ indicates a parallel and preordainedly coherent collection of procedures; if $Con_A = [Proc_A]$ then no information transfer would take place between the procedures that are undergoing execution. If the $\{Proc_A\}$ is a singleton (unit set), then execution does not involve information transfer *between* the procedures; execution is serial. Otherwise if $\{Proc_A\}$ is not a singleton, execution is *incoherent* and probably the process is abortive. (Notice, however, that the compilation of a *Prog*, to form a *Proc*, is a process that *does* involve information transfer; similarly if a *Prog* is read as a *listing*.)

If $\langle\{Proc_A\}, [Proc_A]\rangle$ is executed, information transfer *must* take place *between* the coherent and the as yet incoherent, procedures; in order that the incoherent procedures *become* by recompilation coherent, and thus executable. This is a *concurrent* process.

3.1.5 Execution. The symbolism Ex (Con_A) stands for the execution of some usually concurrent process. Such a concept is not, however, necessarily

a stable concept, and it becomes so only if at least some concepts act upon *Proc* to produce other *Procs* of which some can gain entry into the original concept (reproduction, reconstruction).

3.1.6 Principle 3 (Production and Reproduction). The existence of such concept-making concepts is assumed in the mental-repertoire of any participant A, B, ... It is convenient to distinguish them (artificially) as special operations and to distinguish among them as description building (*DB*) and procedure building (*PB*) operations (though, theoretically based, the differentiation of *DB* and *PB* operations is empirically supported).*

Without debating the exact character of the *DB* and the *PB* operations (for they are likely to differ from person to person), it is possible to distinguish them as classes of operation that act on descriptions to produce other descriptions.

$$DB_A\,(P_A, Q_A) \Rightarrow T_A \qquad DB_A\,(R_A, S_A) \Rightarrow T_A$$

(like, for example, relational operators) and classes of operation that act upon a mixed argument, like

$$PB_A\,(Con_A(P), Con_A(Q), T_A) \Rightarrow Proc_A(T) \text{ in } Con_A(T)$$

$$PB_A\,(Con_A(R), Con_A(S), T_A) \Rightarrow Proc_A(T) \text{ in } Con_A(T)$$

(for example, classes of algorithm building programs).

3.1.7 Principle 4 (Continual Action). Some concepts are invariably undergoing execution; of these, some are and some are not *DB* and *PB* operations. That is, always, for any Z = A, B, ... there is at least one process of each kind

$$Ex\ DB_Z\,(Con_Z(P), Con_Z(Q), T_Z) \Rightarrow Proc_Z(T) \text{ in } Con_Z(T)$$

$$Ex\ DB_Z\,(P_Z, Q_Z) \Rightarrow T_Z$$

$$Ex\ Con_Z(T) \Rightarrow T_Z$$

Thus

(a) It is possible to construct organizationally closed production schemes and thus to speak of stable concepts as maintained entities. .

* Pask and Scott 1972, Pask 1976d. Final Scientific Report, SSRC Research Programme HR/2708/2.

(b) The execution of such a scheme of productions gives rise, for any novel concept, to a progression from its initial appearance ($\{Proc_A\}$ in 3.1.4) up to the parallel execution ($[Proc_A]$ in 3.1.4).

(c) The middle term $\langle\{Proc_A\}, [Proc_A]\rangle$, must intervene between these extremities; hence, information transfer must occur between the concurrent processes.

(d) The execution (indefinite iteration) of a stable concept $Con_Z(T)$ *is* the *topic* T_Z as proposed, loosely, and without specifying a *concept* in Section 2.3.

(e) From (c) stabilization by organizational closure necessarily involves information transfer between procedures undergoing execution; it is this information transfer we identify with "awareness." Similarly, an interaction between Z = A and Z = B (for example, A teaches $Con_A(T)$ to B who learns $Con_B(T)$) also involves information transfer which we identify with consciousness (of A with B of T).

3.1.8 Principle 5 (Coherence and Distinction). By inference from principle 3 and principle 4, given a medium with the particular characteristics ordained by principle 1 and principle 2, any process tends, in isolation, toward coherence; in psychological terms, to fixity, closure, or even rigidity.

Suppose that isolation is somehow maintained. If so, there must, for consistency of the postulates, be means for maintaining the tendency *toward* coherence, postulated, in principle 1 and principle 2 (which cannot apply if *complete* coherence *exists*). Even if interaction (as with some other process) is allowed, there are, by postulate, means for preventing the contravention of principle 1 (again, given its intended interpretation, as a *tendency toward* coherent execution).

This means principle 5 can be expressed by saying the equations that describe the motion of a process have singularities *when* coherence is approached; in psychological terms this may imply a change in attention, or in perspective, or the creation of a further distinguished processor (universe of interpretation). That is, a distinction of the type *Dist* (X,Y) is computed to demarcate independent processors labeled X, Y with interpretations or compilations *Inter* X, *Inter* Y. That is how *Inter* X becomes distinct from *Inter* Y in the first place.

Alternatively, "if there are stable concepts, then the distinctions required for the existence of other stable concepts are computed" the "stable concepts are generalized eigenoperators (Von Foerster, 1976) that yield fixed point solutions (eigenvalues) upon indefinite iteration" or "stable concepts are

discrete, insofar as there are inconceivables" (this latter sense of discreteness is in accord with Glanville's (1977) criticism, on the score of spatial perception) or "under an interpretation which is latent in the discussion, principles 1 to 5 provide a mechanism for preserving information transfer, or consciousness; singularities are the points at which the process would become unconscious, unless some event took place; consciousness is the information transfer required to maintain a tendency toward coherent execution." The conscious process, in other words, satisfies the conditions of Section 1.5.

3.2 Stable Concepts as Units

If $Con_A(T)$ is a stable concept, then Ex $(Con_A(T)) \Rightarrow T_A$ as in Section 2.2.

However, in considering the argument that culminates in Section 3.1.8 we are given the license of interpreting an "internal behavior" (Section 2.2) as involving, under circumstances where concurrency has not yet passed into coherence, as an *image*, without qualification, and in particular, T_A may be A's image or apparition of T (in one sense modality, or many) or, insofar as the execution may take place, wholly or only partially, in a brain, T_A may be A's external behavior.

For example, in flying an aircraft, much of the concept (alias, skill) is executed outside the pilot's brain and constitutes a behavior (for example, of keeping the aircraft on course) though the relation preserved by this regulating behavior is manifest to the pilot as "even flight."

Conversely, if the pilot wishes, he can execute this concept to obtain a mental picture of "even flight." Further, he might describe this picture in terms of "personal constructs" and their values, i.e., personally computed descriptions, generated by executing other stable concepts in his repertoire.

Perhaps the majority of concepts are not *generally* manifest as behaviors (for example, "rectangularity," or "product of numbers"), though they may be. If participant A has a stable concept for "rectangularity" or "multiplication" (or "hope" or "judgment" or "delight") then he can often behave to realize his concept in concrete action; for instance, by drawing rectangles, or by multiplying numbers (by hoping, exercising wisdom, experiencing joy).

The important point is that if A has a stable concept of T then he can *always* issue a series of instructions to some autonomous agent, either some other participant B or an inanimate processor, such that the independent execution of the instructions by the agent is *one* representation of $Con_A(T)$; this representative series of instructions *is* one or more of the *Progs* that constitute part of some $Proc_A(T)$, in $Con_A(T)$ and this may either make its

appearance as the construction of a working model (Section 2.7) *or* figure as an explanation.

By the same token, both DB_A and PB_A operations are *concepts*, taking arguments that are either concepts or the result of executing concepts, or both. They are behaviorally manifest as derivations, later encompassed by a description (Section 2.7 and Section 2.8).

4 SOME CANONICAL ORGANIZATIONALLY CLOSED AND INFORMATIONALLY OPEN PRODUCTION SYSTEMS

At this point, it is possible to draw production systems that are minimal, organizationally closed and informationally open units.

Let Z = A and let T_A be derived from P_A and Q_A (clearly, it is also possible to assert that P_A is derived from T_A and Q_A or that Q_A is derived from T_A and P_A, as in Section 2.5).

If $Con_A(T)$ is stable (similarly, $Con_A(P)$ and $Con_A(Q)$, depending upon A's perspective) then Figure 1 shows the minimal unit as a production system. In this and other pictures "⇒" stands for "produces," and "→" is a collecting arc, meaning that arguments are, and become, available as the output of the productions, some of which "reproduce" (stabilize) the original. The operation is not serially constrained, and insofar as it is concurrent the information transfer between procedures, needed in order to secure the operation of the system, is an awareness on the part of participant A. The system is activated by A's adopting a perspective (for example, T_A when it is a stable concept of T_A) but it is possible to adopt *any* perspective (T,P,Q) except that if the system were isolated, then at least *one* perspective *must* be adopted (principle 4 of Section 3.1.7).

An organizationally closed and informationally open system is potentially aware (notice that productions do not *only* yield one product, and that *other* productions may yield the entities upon which productions operate). This scheme is minimal in the sense stipulated in Section 3.1.

Figure 2 shows the minimal production system for a different participant (or perspective), Z = B, given the postulate that T_B is derived from R_B and S_B (consequently, that R_B is derived from T_B and S_B; S_B from T_B and R_B as in all other statements about stable concepts). That is, insofar as the schemes in Figure 1 or Figure 2 are executed, Z = A and Z = B necessarily adopt perspectives, say T_A and T_B respectively, and supposing that compatible perspectives are adopted (loosely the "same" perspective, though all that is

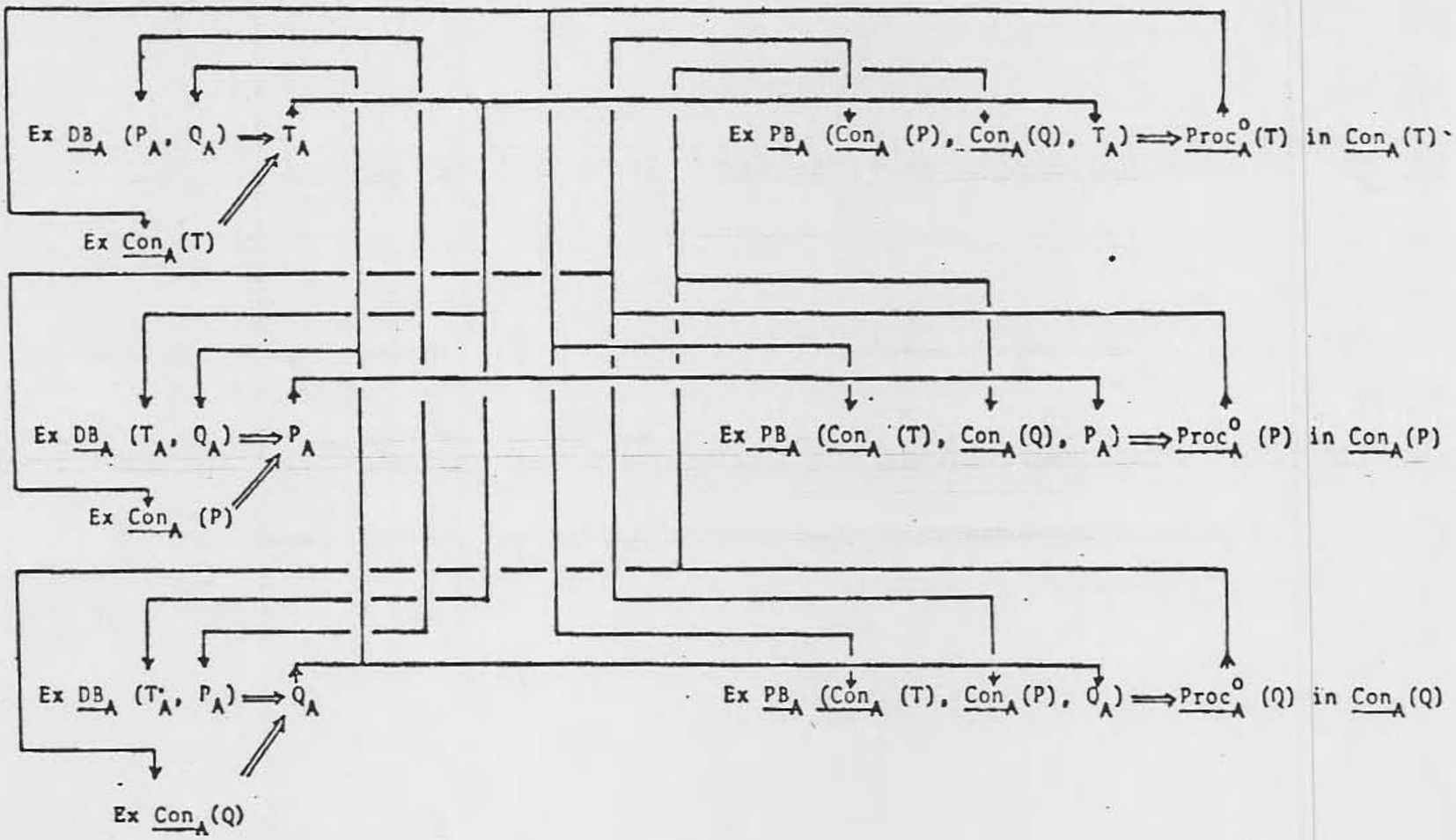


FIGURE 1.

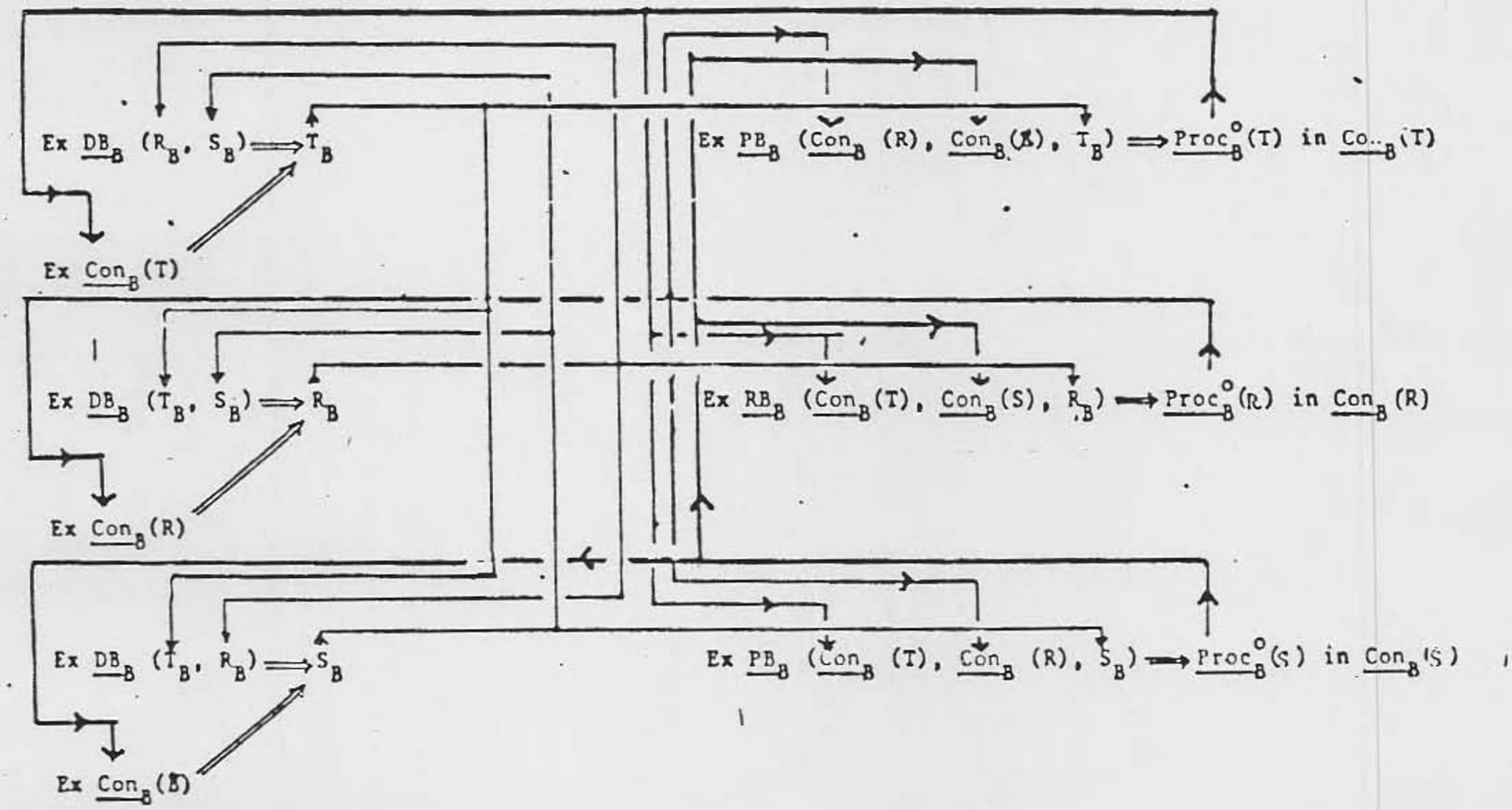


FIGURE 2.

required is a pair of perspectives admitting "coherent" execution), there may be an agreement over an understanding.

Let A and B agree to an understanding of T (where A and B are initially asynchronous, or independent). Their agreement over an understanding of T is minimally represented in the same notation by Figure 3, leading to the simple agreement of Section 2.3, namely

$$T_A \supseteq T_A^* \geqslant T^* \leqslant T_B^* \subseteq T_B$$

But also, since an understanding is involved, and since it is the *postulated* understanding

$$P_A \supseteq P_A^* \geqslant P^* \leqslant P_B^*$$

$$Q_A \supseteq Q_A^* \geqslant Q^* \leqslant Q_B^*$$

$$R_A^* \geqslant R^* \leqslant R_B^* \subseteq R_B$$

$$S_A \geqslant S^* \leqslant S_B^* \subseteq S_B$$

which is represented, in production scheme notation by Figure 4.

However, if the concepts *are* stable and are executed

P_B^* is transformed into a richer P_B

Q_B^* is transformed into a richer Q_B

R_A^* is transformed into a richer R_A

S_B^* is transformed into a richer S_B

It does *not*, of course, necessarily follow that enrichment leads to a condition in which, in the limit, there is isomorphism $P_A \Leftrightarrow P_B$ or $Q_A \Leftrightarrow Q_B$ or $R_A \Leftrightarrow R_B$ or $S_A \Leftrightarrow S_B$ any more than $T_A \Leftrightarrow T_B$.

If the system in Figure 3 is executed, then information transfer takes place between A and B, so that A is conscious with B of T, and vice versa; the concurency is distributed and amounts to a coming about of local (centered at topic T) synchronization of A and B or, equisignificantly, to a coming about of local (centered at T) dependency between the participants.

As noted in Section 2.7 an agreement over the understanding of an

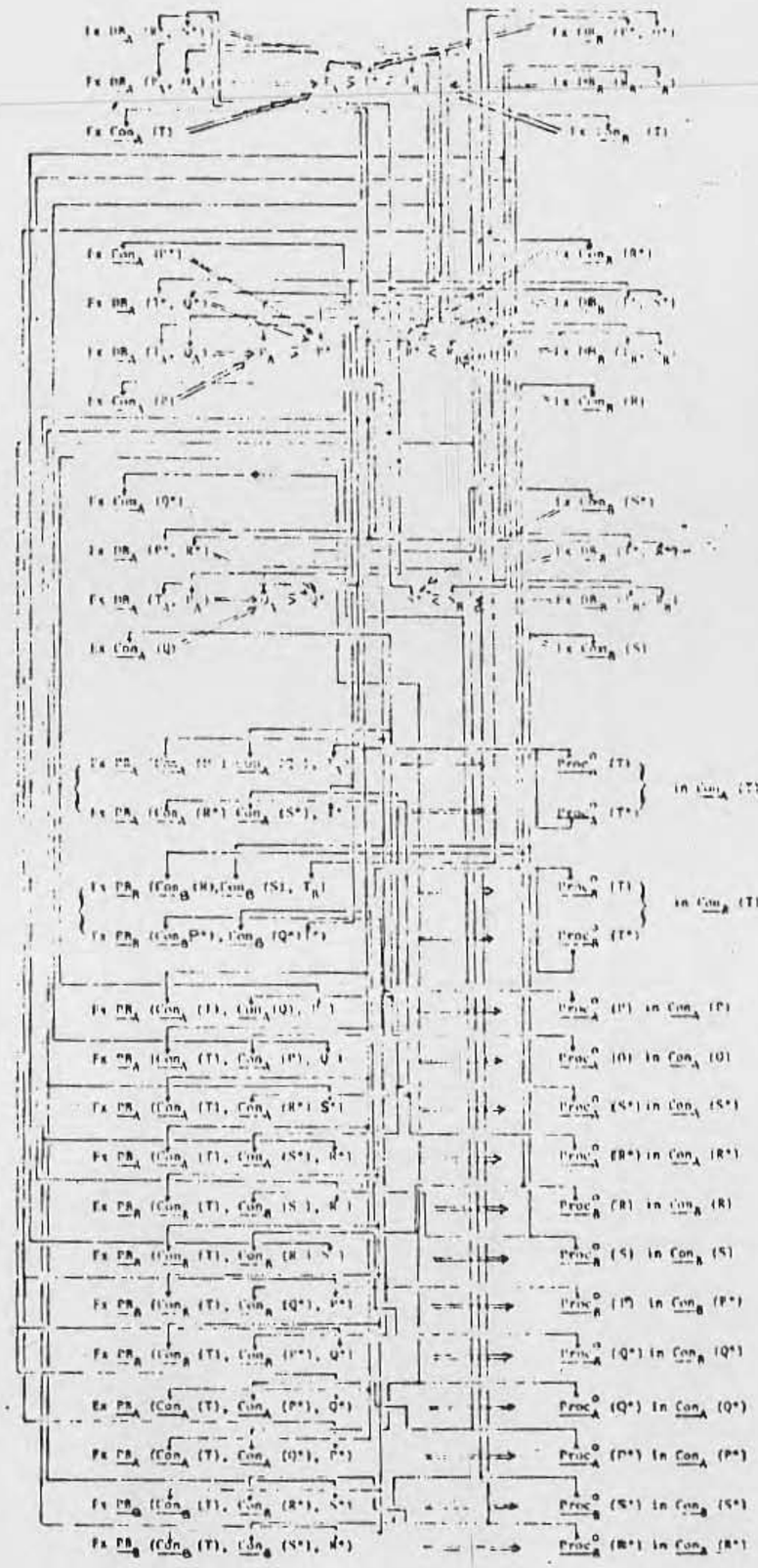


FIGURE 3. L-agreement over common understanding of topic T. A derives T from P and Q. Participant B derives T from R and S. An agreement may be complete or partial depending upon the isomorphic part (for example, T^*) of topic and the similarity of method.

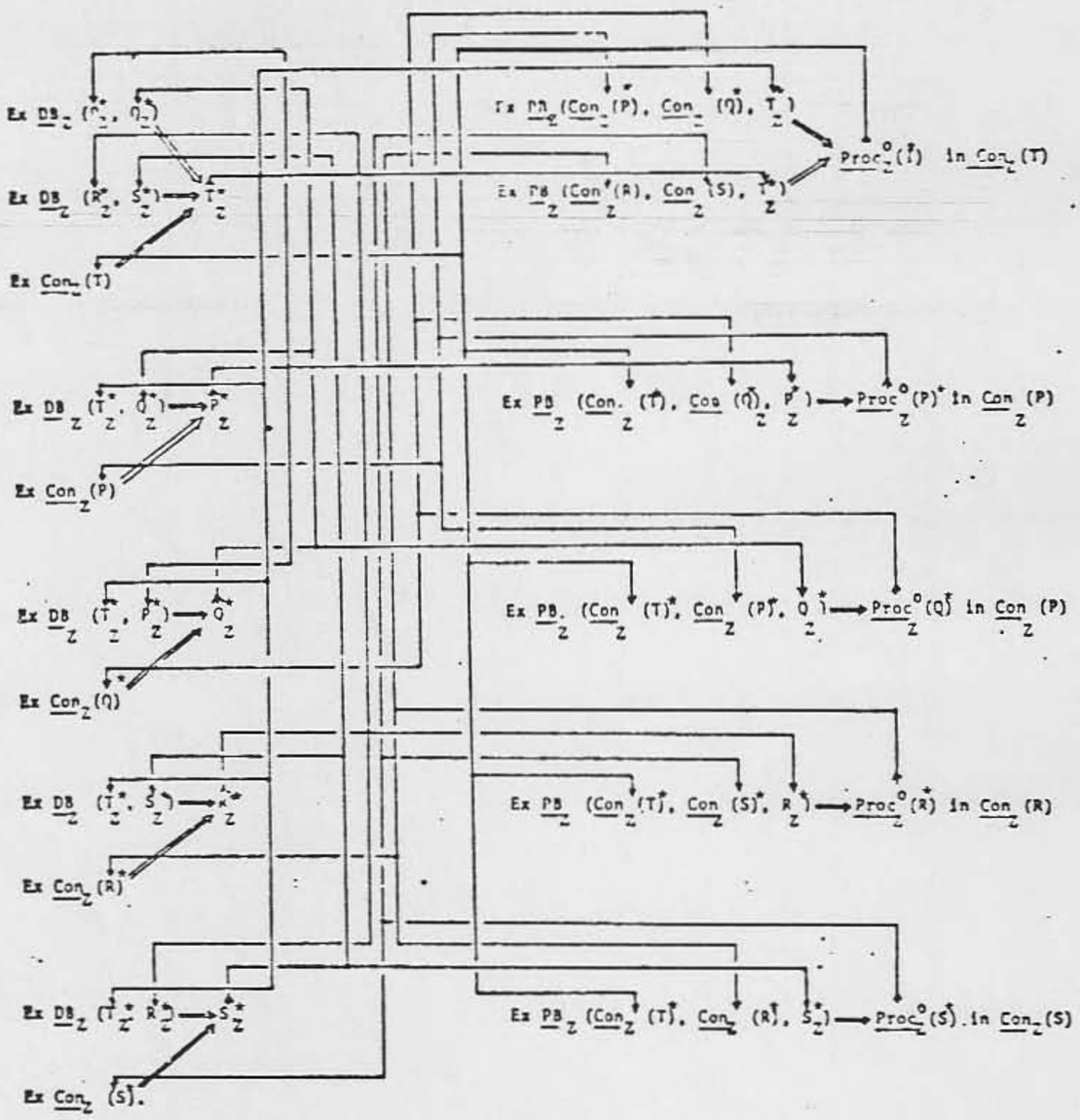
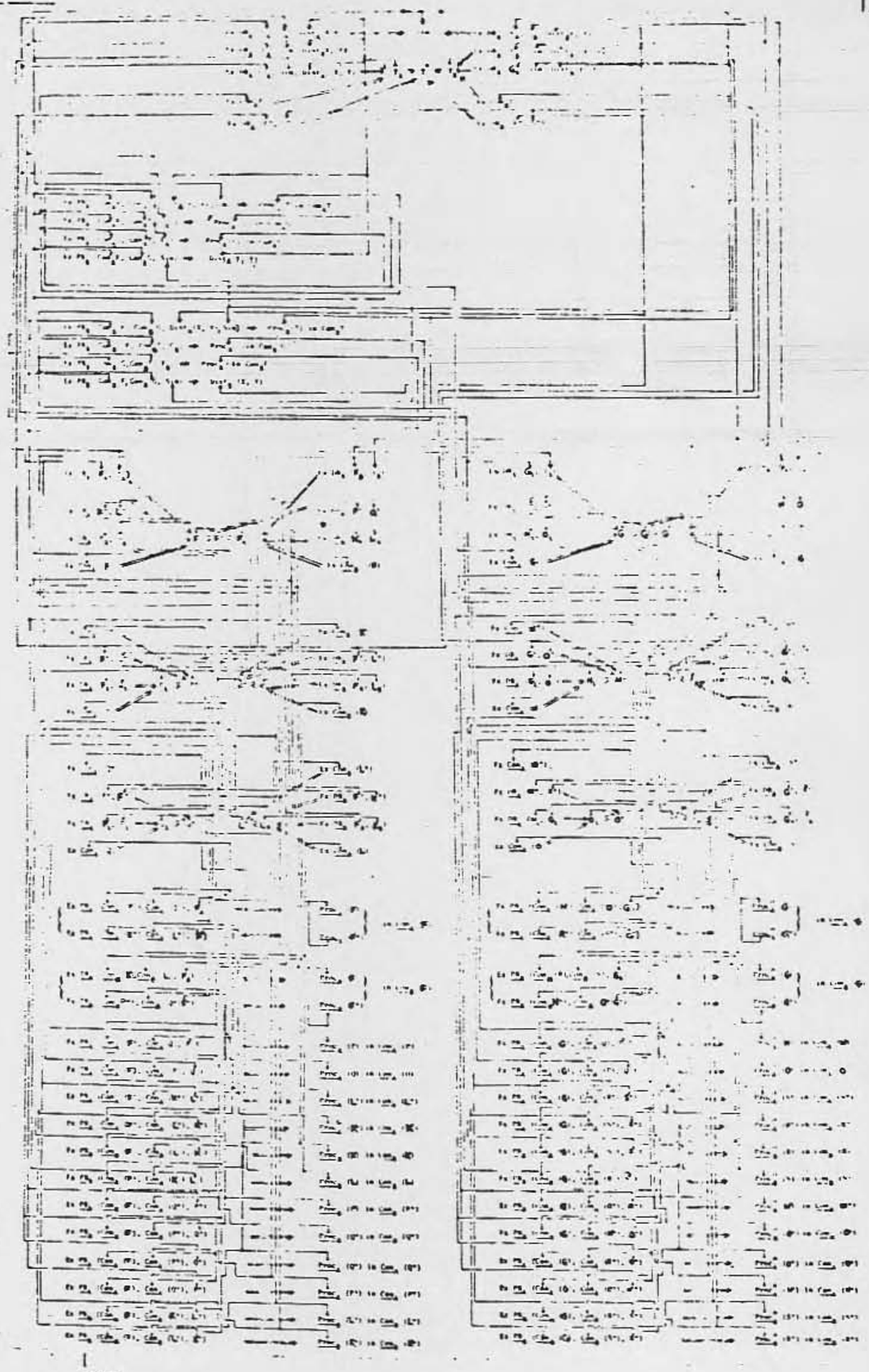


FIGURE 4. Note: Z is a variable indexing participants here Z = A or Z = B.



analogy is more complicated and the *minimal* scheme of productions is complex.

Under the postulate that an analogical topic $\dot{T}_A$ between F_A and G_A is agreed, in respect to an analogical topic $\dot{T}_B$ between F_B and G_B, where (for completeness as well as minimality) A *derives* F_A from P_A and Q_A; G_A from N_A and O_A; that B *derives* F_B from R_B and S_B; G_B from K_B and L_B *minimal* scheme is shown in Figure 5.

There is a simple agreement (Section 2.3) like

$$T_A \supseteq T_A^* \geqslant T^* \leqslant T_B^* \subseteq T_B$$

$$F_A \supseteq F_A^* \geqslant F^* \leqslant F_B^* \subseteq F_B$$

$$G_A \supseteq G_A^* \geqslant G^* \leqslant G_B^* \subseteq G_B$$

$$P_A \supseteq P_A^* \geqslant P^* \leqslant P_B^*$$

$$Q_A \supseteq Q_A^* \geqslant Q^* \leqslant Q_B^*$$

$$R_A^* \geqslant R^* \leqslant R_B^* \subseteq R_B$$

$$S_A^* \geqslant S^* \leqslant S_B^* \subseteq R_B$$

$$N_A \supseteq N_A^* \geqslant N^* \leqslant N_B^*$$

$$O_A \supseteq O_A^* \geqslant O^* \leqslant O_B^*$$

$$K_A^* \geqslant K^* \leqslant K_B^* \subseteq K_B$$

$$L_A^* \geqslant L^* \leqslant L_B^* \subseteq L_B$$

Similar comments apply to the development or enrichment of the initial but stable concepts that are iteratively executed (P_B^*, Q_B^*, R_A^*, S_A^*, N_B^*, O_B^*, K_A^*, L_A^*).

FIGURE 5. Production scheme, representing stable concept of analogy under perspective A and perspective B.

5 METALINGUISTIC STATEMENTS ABOUT CONVERSATIONAL TRANSACTIONS

This paper is written in a metalanguage $L^{\#}$ for making assertions about the conversational language L and the transactions that go on between any participants A, B, ... that engage in discourse. As the initial $L^{\#}$ statement, a participant was defined (in Section 1.2) as an organizationally closed and informationally open system and it was noted (at the end of Section 4) that production systems representing the minimal units that can be isolated from the flux of conceptual activity are defined in the same way "organizationally closed and informationally open systems." A conversation (over which closure is observed by an external observer and described in $L^{\#}$ in order to achieve sharp valued $L^{\#}$ observations of "L agreements over understandings" between A and B) is also an entity of this kind.

The entailment mesh notation will be used, for the purpose of discussion, as an $L^{\#}$ syntax in harmony with the L syntax.

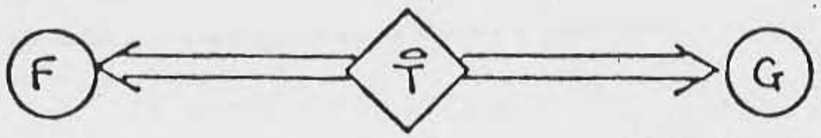
5.1 The Truth Value of Agreement over an Understanding

The inscription of Figure 3 is an L-statement (conversational language statement). The truth value of this agreement over T is a coherence truth, representing the consciousness of A, with B, of topic T; the *content* of their consciousness. It is not at all necessary that this content is veridicially true (or as a matter of fact, even logically true according to the canons of a particular logical scheme). Yet an external observer would like to make a statement, using the metalanguage $L^{\#}$, like "It is true that A and B have a stable concept T^*, that they agree over an understanding of T, this being an L agreement," or "AB(T) is true."

What kind of statement would this metalinguistic, or $L^{\#}$, statement of AB(T) be; one of the sharp valued observations that external observers are able and inclined to make? The veridicially true $L^{\#}$ statement would be (whatever else) an $L^{\#}$ metaphor, designating an $L^{\#}$ analogy. To see this, it is only necessary to notice that the external observer, henceforward *OB*, can observe a similarity (T^*), based upon other similarities (P^*, Q^*, and R^*, S^*), insofar as he adopts a perspective (so that T^* is being understood, rather than P, Q, R, S) *and* he makes a distinction between A and B. Any one of infinitely many possible distinctions (biological, cultural, and so on) are legitimate, a particular distinction being denoted $Dist_{OB}(A,B)$.

To represent this state of affairs, all that is needed is a means of distin-

guishing $L^{\#}$ from L analogies. It is convenient to adopt the convention that $L^{\#}$ analogies are shaded, whereas L analogies (as before) are not. The convention is thus:



For L analogies as before

For $L^{\#}$ analogies, the fresh notation

Using this symbolism, it is possible to represent the $L^{\#}$ statement, AB(T), as a veridicially true but *analogical* $L^{\#}$ statement of the L agreement concerning the understanding of topic T by A and B; this (or any other type of agreement), having a coherence truth; strictly "as seen *reflectively* by A and B, *relative* to their conversational domain which contains topic T (perhaps because they constructed a stable concept for T, de novo; or equally, because topic T was purveyed by some other theorist).

The $L^{\#}$ statement is shown in Figure 6, using entailment mesh notation. It is an $L^{\#}$ entailment mesh pruned under the perspective adopted, namely T.

5.2 The Status of Agreement over Understanding an Analogical Topic

Now, if the external observer exists and is able to make $L^{\#}$ statements about L agreements, he is also able to observe that A and B do, from time to time, reach agreement over understanding L analogies. Such agreements are, as before, credited with a coherence truth signifying the content of A's consciousness with B (or B's consciousness with A) of a topic called $\dot{T}$. The necessary production system for this kind of stable concept sharing is shown and interpreted in Fig 5. Thus participant A has a personal theory about

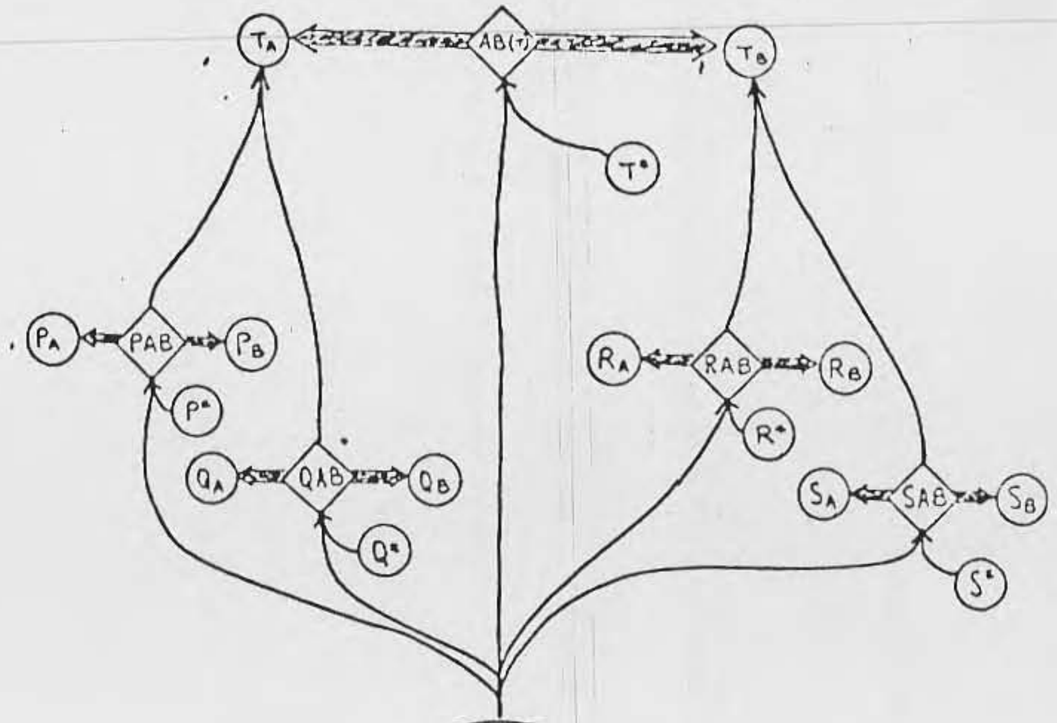
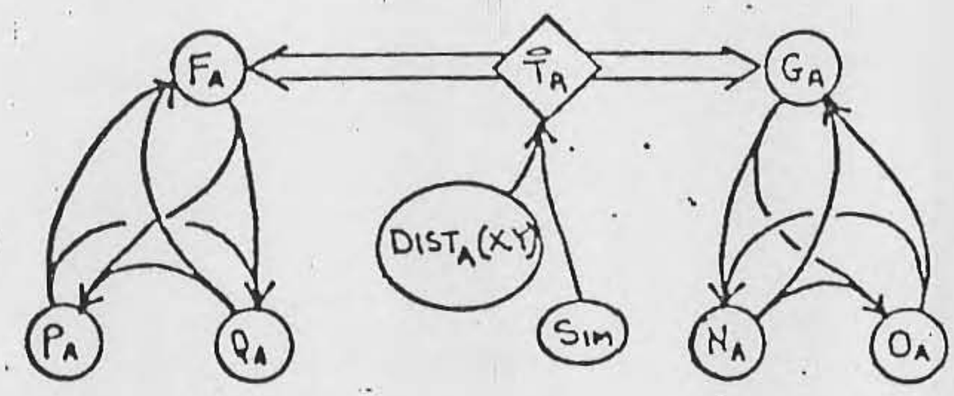
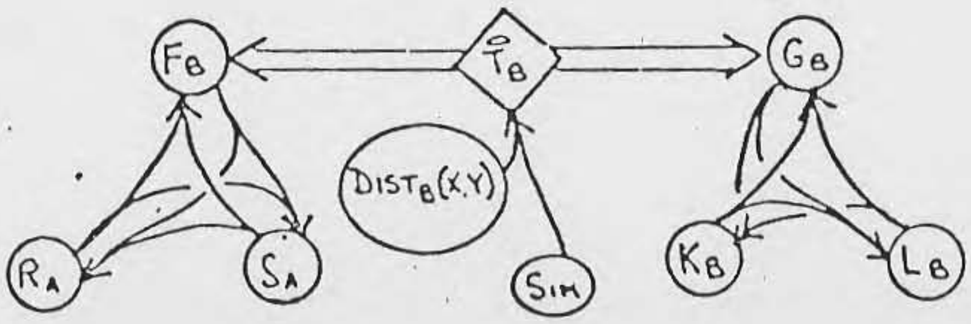


FIGURE 6. An $L^{\#}$ analogy (designated by an L metaphor), AB(T), corresponding to an external observer's inscription of agreement and understanding (in L, by participants A and B) of an ordinary topic, T, with common and agreed part, T^*.

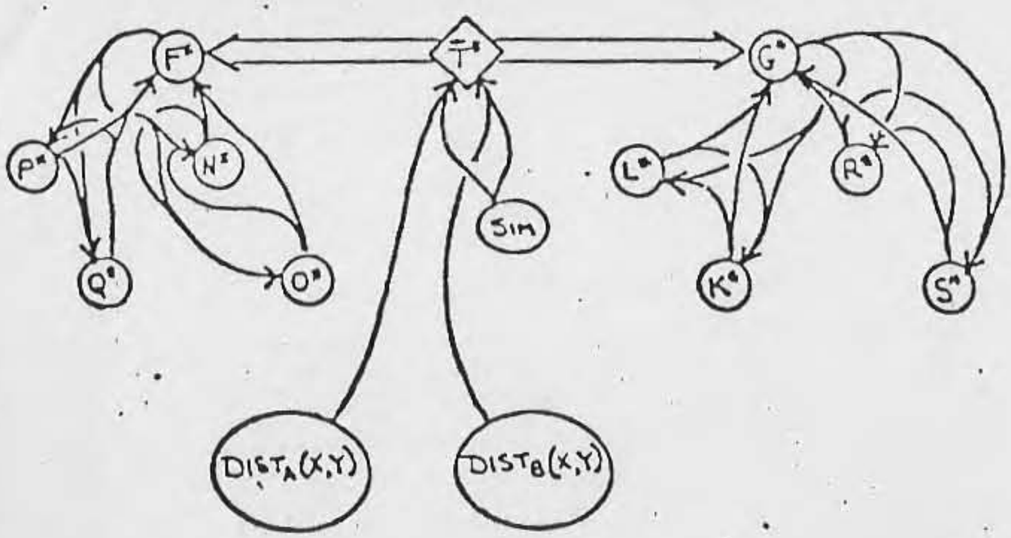
an L analogy, $\dot{T}_A$, between topics F_A and G_A, given the distinction $Dist_A(X,Y)$, and the similarity, *Simi*, as stated in Section 4, namely



By the same token, participant B has a personal theory about an L analogy, $\dot{T}_B$, between topics F_B and G_B, given the distinction $Dist_B(X,Y)$ and the similarity, *Simi*, and the entailment mesh picture expressing the statement of Section 4 is



These are static, shorthand, inscriptions for the production scheme shown in Figure 5, before an agreement is reached. After the agreement is reached, there is a common scheme of productions in the mental repertoires of both A and B that can be pictured below (where $\dot{T}^*$ is the common analogical topic, based on possibly different distinctions $Dist_A(X,Y)$ and $Dist_B(X,Y)$).



This is an L (conversation language) statement and it has a coherence truth value.

Suppose that an A,B agreement over an understanding with content $\dot{T}^*$ is

to be represented by an external observer, in the metalanguage $L^{\#}$, in the same way as the $L^{\#}$ statement "AB(T^*) is true," of Figure 6. The result is Figure 7, where, as before, $Dist_{OB}(A,B)$ is a distinction between the participants.

It is once again a pruned $L^{\#}$ entailment mesh in which the L analogies are interleaved with L analogies (notice that all the lowest topics in this pruning are $L^{\#}$ analogies, though the terms they relate are unspecified in the picture).

5.3 Significance of Analogies in L and in $L^{\#}$

Notably, Figure 7 brings out the point that the difference (if any difference exists) between the pruned $L^{\#}$ mesh of an outside observer and the L mesh of the participants, that images a dynamic production scheme (Figure 5), lies in (a) the fact that the distinctions in $L^{\#}$ analogies, imaging agreements, are like

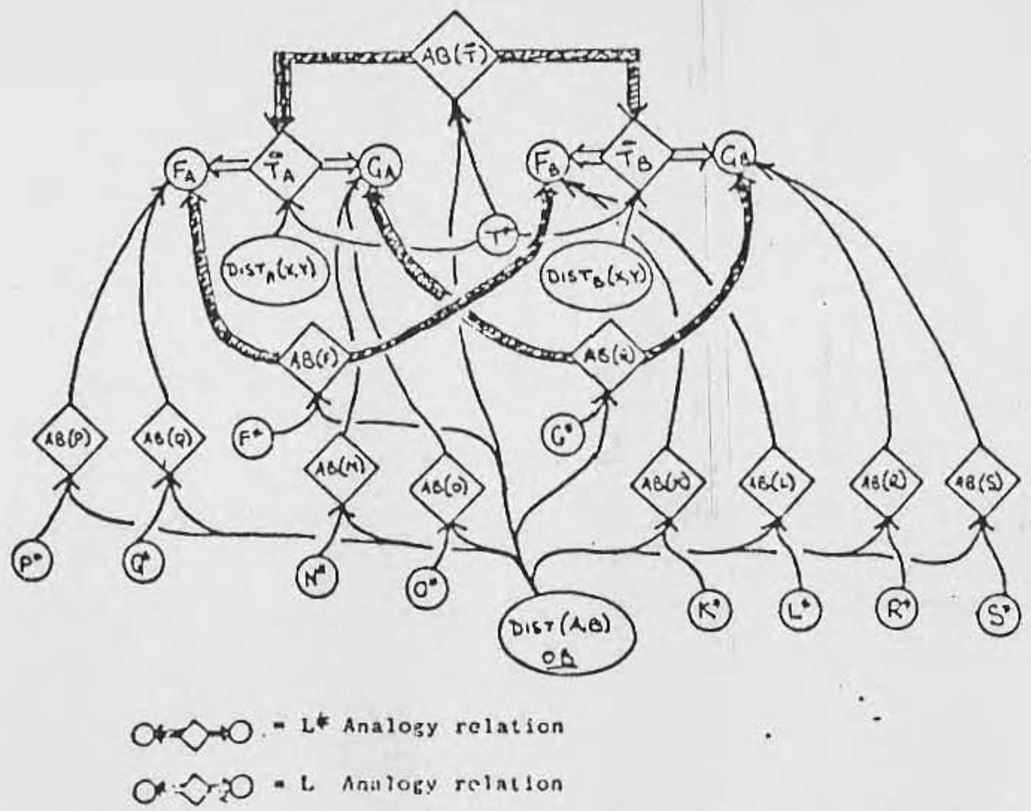


FIGURE 7. Minimal construction, in $L^{\#}$, for AB(T) if T is an analogy between F and G derived by A as F from P and Q, G from N and O; by B as F derived from K and L for G from R and S.

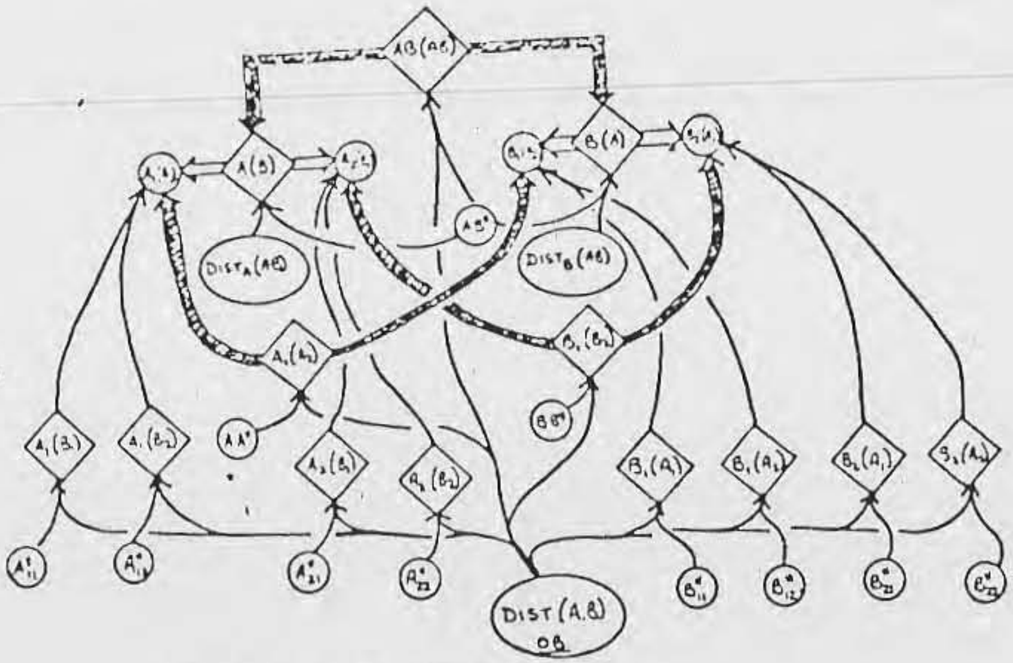


FIGURE 8. Minimal construction, in $L^{\#}$, for AB(AB) (the L-topic AB) is an analogy between A(B) and B(A). AB^* is common image of A and B, that is, image, as shared by A and B, mutually. *OB* has no grounds for distinguishing $A_1(A_2)$, $A_2(A_1)$ or AB(AB), BA(AB).

$Dist_{OB}(A,B)$, whereas those in the L analogies (between acoustics and optics, or mechanics and electricity, or universes, in general) are like $Dist_A(X,Y)$ and $Dist_B(X,Y)$; and (b) that the external observer adopts a perspective (as the participants may do also); hence, the pruning.

The question arises of whether or not these two differences (a) and (b) are significant or salient differences.

Now, of the two (b) is definitely not salient (fundamental more than a convenience), for any participant A,B can, by definition, adopt a perspective with respect to agreement over an understanding, just as the observer *OB* can adopt any or all perspectives. If it turns out that (a) is in no way salient (fundamental more than a convenience) either, then there is no essential difference. It seems to me that (a) is *not* salient; for surely, A and B may distinguish themselves, i.e., A can see himself distinct in any coherent way from B and vice versa, B from A. I have tried to show this in Figure 8, where A and B are imaged in the process of "self inquiry" or "interpersonal

interaction"; they are getting to know each other, to understand each other (to agree to an understanding of each other's beliefs, which certainly does not imply that they agree *about* these beliefs; in fact, they may disagree, yet know why they disagree. The L topic (an analogic topic) that A and B agree to understand is AB (their mutual or shared beliefs) and, consequently, the L representation of any AB agreement over an understanding of AB is signified AB(AB) and is an L analogy relation (as in Bateson or Laing).

The slightly barbaric notation of Fig 8 is chosen to simplify the scheme so far as possible. $L^{\#}$ analogies are designated like the companion L analogies by bracketing. Thus AB(AB) is the L analogy seen by *OB* to hold when A and B agree to understand their views of each other (A's view of B is A(B) and B's view of A is B(A)). These, in turn, relate analogies between systems of belief, or personality, or theory, designated by specific perspectives $A_1, A_2, \ldots B_1, B_2, \ldots$ As before, the similarity part of the analogy is designated by an asterisk (as in AB^*, or A_1, A^*, B_1, B^*) and the distinctions of analogies by *Dist.*

Consider the $L^{\#}$ analogy AB(AB), with similarity, like the L analogies A(B) and B(A), consisting in AB^*; the common part of A's understanding of B and B's of A. How do these analogies AB(AB), A(B), B(A), differ? The difference of Figure 8 that A and B computed distinctions $Dist_A(X,Y)$ and $Dist_B(X,Y)$ whereas *OB* computed the distinction $Dist_{OB}(A,B)$ has evaporated since, in this case, A and B compute $Dist_A(A,B)$ and $Dist_B(A,B)$. The difference between *OB* and some other symbol, for example C (in Z = A, B, C), regarded on a par with the participant-symbols A and B, seems to depend entirely upon the fact that *OB* (or C) has opted to adopt a perspective (as A and B could do just as well by definition) thereby imposing a directionality upon the mesh, relative to which statements are made.

5.4 The Benevolent Trickery of Reflective and Relativistic Theories

Differentiation between $L^{\#}$ and L is really a conjuring trick. Any participant may elect to stand upon a stage speaking $L^{\#}$ rather than L, and while he does so, to assert the veridical truth values of strictly $L^{\#}$ analogical statements that denote the L analogies which would otherwise represent coherence and agreement over an understanding. Such tricks are often useful, but should be recognized as tricks (the legerdemain is revealed in Figure 8, where the participants are making the same *kind* of distinction, perhaps even the *same* distinction as *OB* the conjuror). The stage on which *OB* stands is no more

than a perspective (and I do not deny that some perspectives may be more useful, even more comprehensive, than others in the context of a participant who is able to adopt them). For example, from the perspective of *OB* in Figure 8, it is possible to offer the following cogent interpretations of the tersely named entities in the picture.

Identity Interpretation

- A_1 one aspect of A's personality, one perspective
- A_2 another aspect or perspective
- A the integrity of these perspectives (organizational-closure, as in Varela)

and similarly for B_1, B_2, B. Another, different interpretation is

Temporality Interpretation

- A_1 A's past
- A_2 A's future (*or* A's present)
- A A at the moment (*or* A's specious present) (invariance of informationally open process, as in Petri or Reichenbach's discussion of Lewin's "Genidentity").

and similarly for B_1, B_2, B.

Merely to replace "*OB*" by "C" (and consequently, to replace "$Dist_{OB}$(AB)" by "$Dist_C$(AB)) in Figure 8 renders all analogies in the picture L-analogies (not $L^{\#}$ analogies as some were originally). However, this expedient is relatively unilluminating as the replacement is incomplete; it provides C's view, admittedly another participant's view, of the dialogue between and within the participants A and B. The reality is more complex; if C *is* a participant as supposed, then C *is* so because C is on a par with A or B who are also in a position to look at the dialogue between and within each other (or C, or any participant).

5.5 A Minimal Substitution of $L^{\#}$ into L

A minimal $L^{\#}$ into L substitution, which makes this point for A and B (suggesting the role of C), is shown in Figure 9. One way of reading the picture is to notice that the L-analogy AB(AB) is supported either by the similarity AB^* *and both* of the distinctions $Dist_A$(A,B), $Dist_B$(A,B) *or* by the

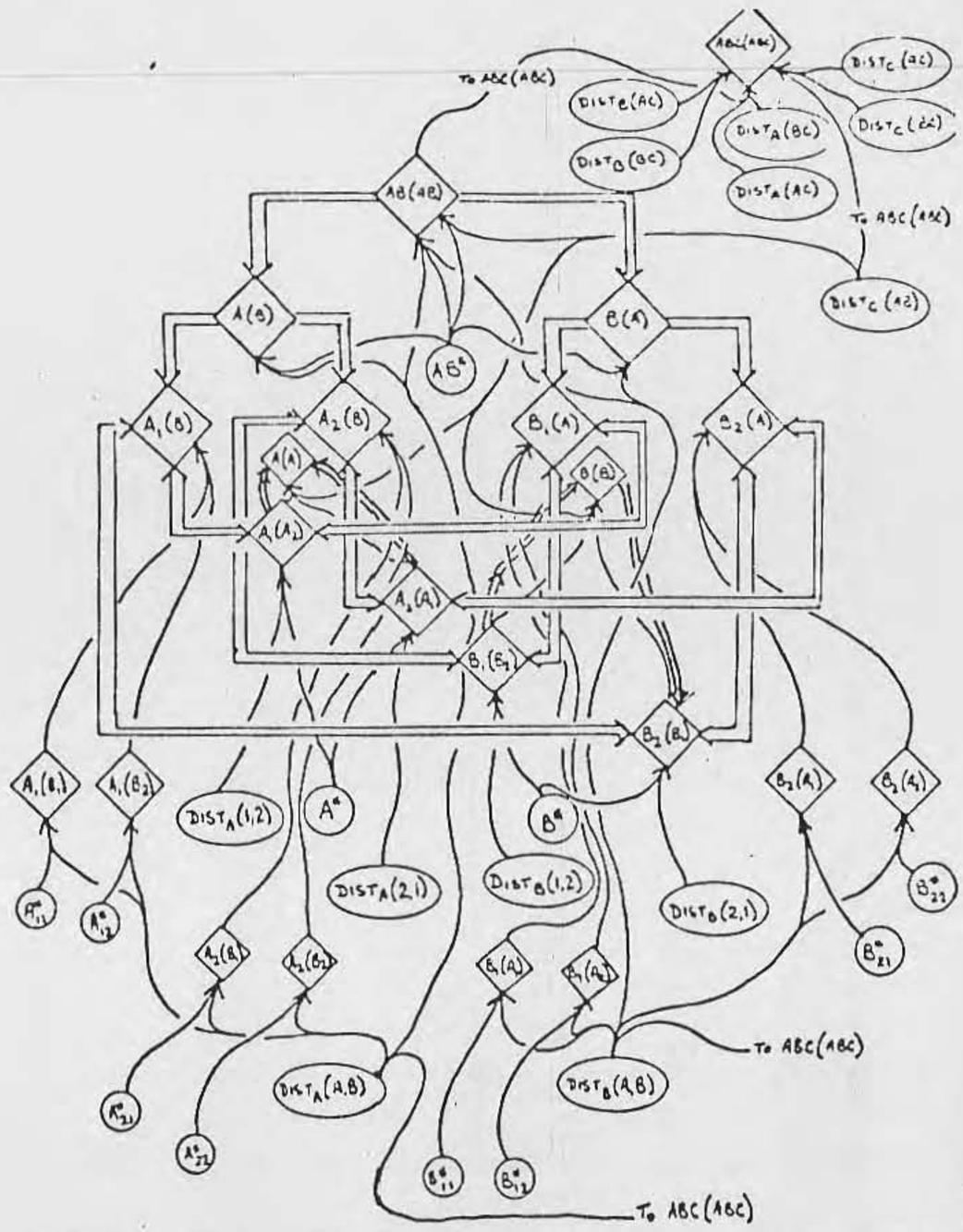


FIGURE 9. An L-analogical construction, minimally representing participants and their conversational interaction as imaged by L-analogies. A further construction involving a participant, C, the distinction $Dist_C$(AB) and an L analogy, ABC(ABC), is sketched but not completely exhibited.

similarity AB^* *and* the distinction computed by C, namely $Dist_C$. At the upper right hand of the picture I have sketched, or indicated, the existence of an analogy ABC(ABC), which it is tempting to regard as the *representation* of a "social reality" that may be viewed differently by participants A, B, C, or any combination of them according to the distinctions which support it.

Let me qualify the reflective entailment mesh of Figure 9 and the suggested "social reality" by the comment that (in common with any other entailment mesh at all) it is a *static* and *shorthand representation for a process* governed by a production scheme; as for example, Figure 7 represents a process governed by the production scheme of Figure 5. Such processes can exist, insofar as the necessary independencies and possibilities of information transfer (local dependency, local synchronicity) are computed, and induced within the processor by $Dist_A(A,B)$, $Dist_B(A,B)$, and the rest of them. The participants who *are* the processes in question appear (in the notation adopted) as letters A, B, and C. They are represented in the entailment mesh as the pairs of analogies A_1 (A_2), A_2 (A_1) and B_1 (B_2), B_2 (B_1) or, alternatively, as the derived terms A(A) and B(B), obtainable if some reference perspective is adopted (here, by C) and the *temporal interpretation* (in contrast to the *identity interpretation*), is adopted by the referee. If t_C is C's time sense and Δt_C an interval of C's time, then we obtain a directed analogy as in Figure 10.

When Rescher speaks of a command logic, or when Aqvist, Belnap,

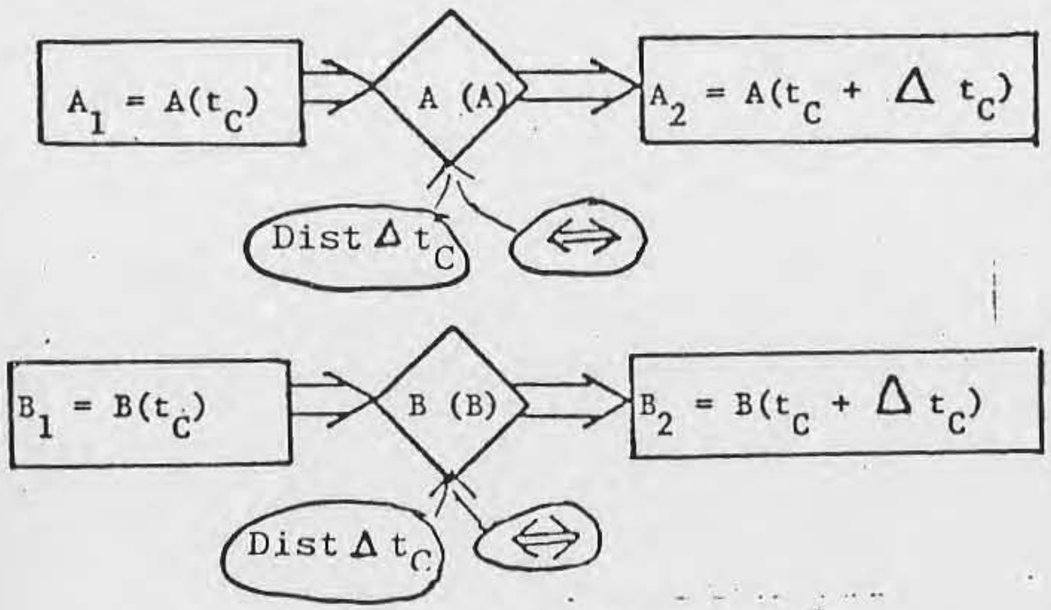


FIGURE 10. Directed analogies of Section 5.4.

Harrah and many later authorities speak of interrogation logic, they allude to a metatheory *about* commands and questions which comments obliquely, at most, upon the *act* of questioning and commanding. For example, in Rescher's command logic a command is "terminated." This is a metastatement, namely an $L^{\#}$ statement; for example, to the effect that A told B to take his hat off when a lady came into the room, that a lady did come into the room, and that B duly removed his hat. Thus "termination" has a veridical truth value (Lewis and Cook, 1969, clearly exhibit this point) but "termination" is *not* "obedience" (nor of course, is it supposed to be).

In fact, these $L^{\#}$ metastatements are *about* L transactions that go on in L; they are, every one, $L^{\#}$ analogies *for* an agreement over (part of) an understanding of a topic (for example, hat removal when ladies come into the room) founded upon a distinction $Dist_{OB}(A,B)$ between A and B.

Consider however, the commands that A *really* gives to B or the questions A *really* asks of B. These are L statements. Insofar as L-commands are *really* given, they are sensed and obeyed (or not); insofar as L-questions are really asked, they are heeded and answered (or not).

The dynamics of commanding and questioning of obeying and answering are production schemes such as Figure 3 or Figure 5. Their meaning is A's consciousness with B, or B's consciousness with A of the commanded or questioned action. The form of the process is an assymetric L analogy (like Figure 10) but pruned from the perspectives of A or B.

Obedience, answering, and heeding have coherence *truth* but not veridi-

5.6. Allegories designating coherent beliefs

A story is the interweaving of forms construed by A or B (in Section 5.5). Its enactment is the process (of agreement or not) and its experience is the consciousness of the participants (as individuals or as socieities with myths, folklore, and conventional wisdom, prejudice, and fantasy).

Any coherent analogical mesh has an infinity of distinctions which may be successfully computed to comprehend or satisfy the distinction required by the analogy (there is also an infinite number of distinctions that do not, as well). It follows that there are indefinitely many* stories, generable by pruning or unfolding an allegory, and computing the required distinctions. Though an indefinite number of these will work (make sense, have coherence), in

*Glanville insists (I believe, rightly, in view of his recent papers and those by Varela) that I use "indefinitely many" for the pruning or unfoldment computations that preserve topics and reserve "infinite number" for the computation of the various distinctions.

some (class of) universes held apart by the computed distinctions, there are just as many that do not work (do not satisfy storyhood, fail to be parables).

REFERENCES

Abel, C. 1977. *Architrainer.* Internal Memorandum, Department of Architecture, Portsmouth Polytechnic.

Andreka, H., Gergely, T., and Nemeti, I. 1975. *Easily comprehensible mathematical logic and its model theory.* Hungarian Academy of Sciences, Central Research Inst. for Physics, Budapest.

Ashby, W. R. 1956. *Design for a brain.* London: Chapman and Hall.

Atkin, R. H. 1973. *Mathematical structures in human affairs.* London: Allen and Unwin.

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., and Mair, J. 1968. *The evaluation of personal constructs.* New York: Academic Press.

Bateson, G. 1973. Steps towards an ecology of Mind Paladin, London.

Belnap, N. D., Jr. 1969. Aqvist's corrections-accumulating question-sequences. *Philosophical logic*, eds. J. W. Davis et al. Dordrecht: D. Reidel.

Braten, S. 1977. *The human dyad. Systems and simulations.* Institute of Sociology, University of Oslo.

Bykhovsky, V. K. 1974. Control and Information Processing in Asynchronous Processor Networks. *Proc. Finland USSR Symposium on Micro Processors and Data Processors*, Helsinki, Vol. 1.

Cherry, C. 1957. *Human communication.* Cambridge, Mass.: MIT Press, and New York: Wiley.

Erhardt, W., and Gioscia, V. 1977. The est standard training. *Biosci. Comm.* 3:104–122.

Feurzeig, W., and Papert, S. 1969. Programming languages as a conceptual framework for teaching mathematics. In *Programmed learning research*, eds. F. Bresson and M. de Montmollin, Paris: Dunod.

Fransella, F., and Bannister, D. 1977. *A manual for repertory grid technique.* London: Academic Press.

Gaines, B. R. 1977. *System identification approximation and complexity.* Man Machine Systems Laboratory, University of Essex, Colchester.

Gergely, T., and Nemeti, I. 1977. *Various Publications*, Institute of Applied Computer Science, Hungarian Academy of Science, Budapest.

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. 1976. *Is architecture just a hollow space or is it the empty set?*, London: AAQ.

Glanville, R. 1978. What is memory that it can remember what it is? In: *Progress in cybernetics and systems research, Vol. IV*, eds. R. Trappl, and G. Pask, pp. 27–37. Washington: Hemisphere.

Glushko, V. 1966. *Introduction to cybernetics.* London: Academic Press.

Goguen, J. A. 1969. The logic of inexact concepts. *Synthese* 19:325–373.

Goguen, J. A. 1975. Objects. *Int. J. Gen. Syst.* 1:237–243.

Harrah, D. 1963. *Communication: A logical model.* Cambridge, Mass.: MIT Press.

Harrah, D. 1973. The logic of questions and its relevance to instructional science. *Instruct. Sci.* 1(4):447–468.

Herbst, P. G. 1976. *Alternatives to hierarchies.* Leiden.

Holt, A. 1972. Comments in *Our own metaphor*, Bateson, M. C. New York: Knopf.

Howe, J. A. M., and O'Shea, T. 1976. *Papers and remarks at the SSRC seminar on computer aided learning.* Warwick University.

Kelly, G. A. 1955. *The psychology of personal constructs*, Vols. 1 and 2. New York: Norton.

Laing, R.D. 1961, Self and Others, Tavistock, London

Lewis, B. N., and Cook, J. A. 1969. Towards a theory of telling. *Int. J. Man Mach. Studies* 1(2):129-179.

Lewis, B. N., and Pask, G. 1968. The use of a null point method to study the acquisition of simple and complex transformation skills. *Brit. J. Math. Stat. Psychol.* 21:61–81.

McCulloch, W. S. 1965. *Embodiments of mind.* Boston: MIT Press.

Maturana, H. R. 1969. Neurophysiology of cognition. In *Cognition a multiple view*, ed. P. L. Garvin, New York: Spartan Books.

Maturana, H. R. 1975. The organisation of the living: A theory of the living organisation. *Int. J. Man Mach. Studies* 7:313–332.

Montague, R. 1976. *Formal Philosophy*, ed. R. H. Thomason, Yale University Press.

Pappert, S. 1970. Teaching children thinking. *Proc. IFIP Conf. on Computer Education*, Amsterdam.

Pask, G. 1972. A fresh look at cognition and the individual. *Int. J. Man Mach. Studies.* 4:211–216.

Pask, G. 1975a. Cybernetic theory of cognition and learning. *J. Cybern.* 5:1–90.

Pask, G. 1975b. *The cybernetics of human learning and performance.* London: Hutchinson.

Pask, G. 1975c. *Conversation, cognition and learning.* New York: Elsevier.

Pask, G. 1976a. Conversational techniques in the study and practice of education. *Brit. J. Educ. Psychol.* 46:12–25.

Pask, G. 1976b. Styles and strategies of learning. *Brit. J. Educ. Psychol.* 46:128–148.

Pask, G. 1976c. *Conversation theory: Applications in education and epistemology.* New York: Elsevier.

Pask, G. 1977a. Knowledge innovation and learning to learn. *Proceedings NATO-ASI 'Structural/Process' Theories of Complex Human Behaviour.* Banff Springs, Canada, Alphan an den Rijn, Noordhoff.

Pask, G. 1977b. Organisational closure of potentially conscious systems *Proceedings NATO Congress on Applied General Systems Research Recent Developments and Trends.* Binghamton, New York, (in press), and *Realities conference*, est Foundation, San Francisco, 1977.

Pask, G. 1977c. *Problem solving.* Monograph IET Open University and Ford Foundation.

Pask, G. 1978a. A cybernetic and conversation theoretic approach to conscious events in learning and innovations. *Proceedings 23rd Annual Conference of JUREMA*, Zagreb, Yugoslavia, April.

Pask, G. 1978b. A conversation theoretic approach to social systems. *Simulating modelling and knowing social systems.* Amsterdam: Martinus Nijhoff, eds. R. F. Geyer, and J. van der Zouwen, 4th World Congress of Cybernetics and Systems.

Pask, G., and Scott, B. C. E. 1972. Learning strategies and individual competence. *Int. J. Man Mach. Studies* 4:217–253.

Pask, G., and Scott, B. C. E. 1973. CASTE: A system for exhibiting learning strategies and regulating uncertainty. *Int. J. Man Mach. Studies* 5:17–52.

Pask, G., Scott, B. C. E., and Kallikourdis, D. 1973. A theory of conversations and individuals (exemplified by the learning process on CASTE). *Int. J. Man Mach. Studies* 5:443–566.

Pask, G., Kallikourdis, D., and Scott, B. C. E. 1975. The representation of knowables. *Int. J. Man Mach. Studies* 17:15–134.

Petri, G. A. 1964. Communication with automata (Trans. F. Green, Jr.). *A supplement to Tech. Documentary Rept. 1*, Rome Air Development Centre, Contract AF30(602) 3324.

Reichenbach, R. 1957. *The philosophy of space and time.* London: Dover.

Rescher, N. 1973. *The coherence theory of truth.* London: Oxford University Press.

Shannon, C. E., and Weaver, W. E. 1949. Mathematical theory of communication. Urbana, Ill.: University of Illinois Press.

Spencer-Brown, G. 1969. *The laws of form.* London: Allen and Unwin.

Thomas, L. F. 1970. *Kelly McQuittie: A computer program for focussing the*

repertory grid. Centre for the Study of Human Learning, Brunel University, Uxbridge.

Thomas, L. F. 1971. Interactive method of eliciting Kelly grids. Paper presented at the Occupational Section BPS Conference, published in *Proceedings.*

Varela, F. 1975. A calculus for self reference. *Int. J. Gen. Syst.* 2:5–24.

Varela, F. and Goguen, J. 1976. Arithmetic of Closure, Proceedings, Third European Meeting on Cybernetics and Research, Vienna.

Von Foerster, H. 1976. An epistemology for living things. In: *L'Unite de l'Homme*, ed. E. Morin, Editions de Sevel, Paris.

Von Foerster, H. 1976. *Various papers on microfische.* Biological Comp. Lab. University of Ill., Illinois Blueprint Corp.

Von Foerster, H. 1978. *Contribution to sourcebook est Realities International Conference.* San Francisco.

Zadeh, L. A. 1974. *A fuzzy algorithmic approach to the definition of complex or imprecise concepts.* Electronics Res. Lab. College of Engineering, University of California, Berkeley.

Zadeh, L. A. 1976. The theory of fuzzy sets. In: *Encyclopaedia of Computer Science and Technology*, eds. Belser, Halzman and Kent, Marcel Dekker.

Zadeh, L. A. 1977. *PRUF: The meaning representation language for natural language.* Elect. Eng. Res. Lab., UCLA, Internal Rept. No. ERL-M77/61.

Received October 1978
Submitted by R. Trappl